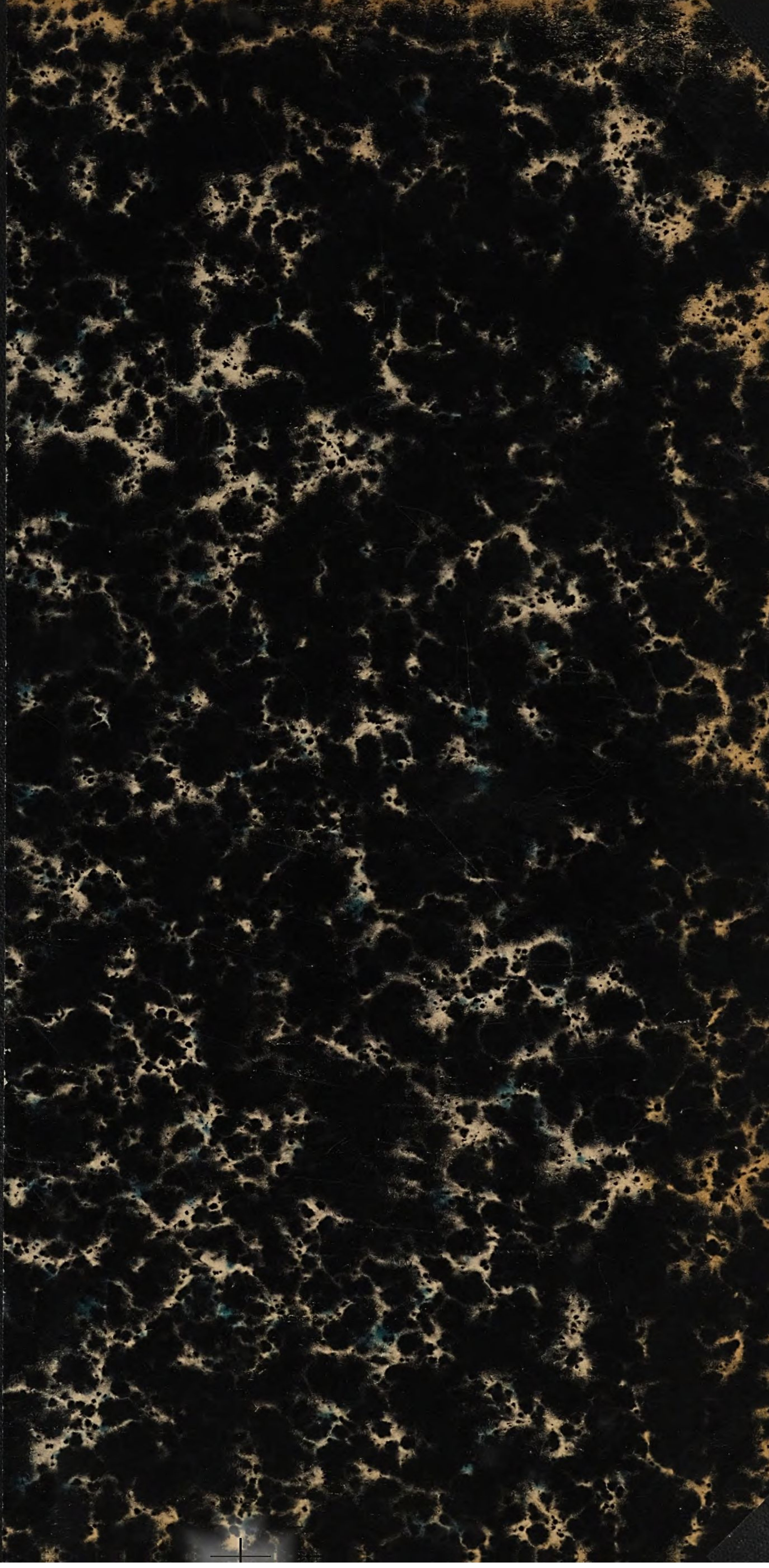


Tech.  
1440.5





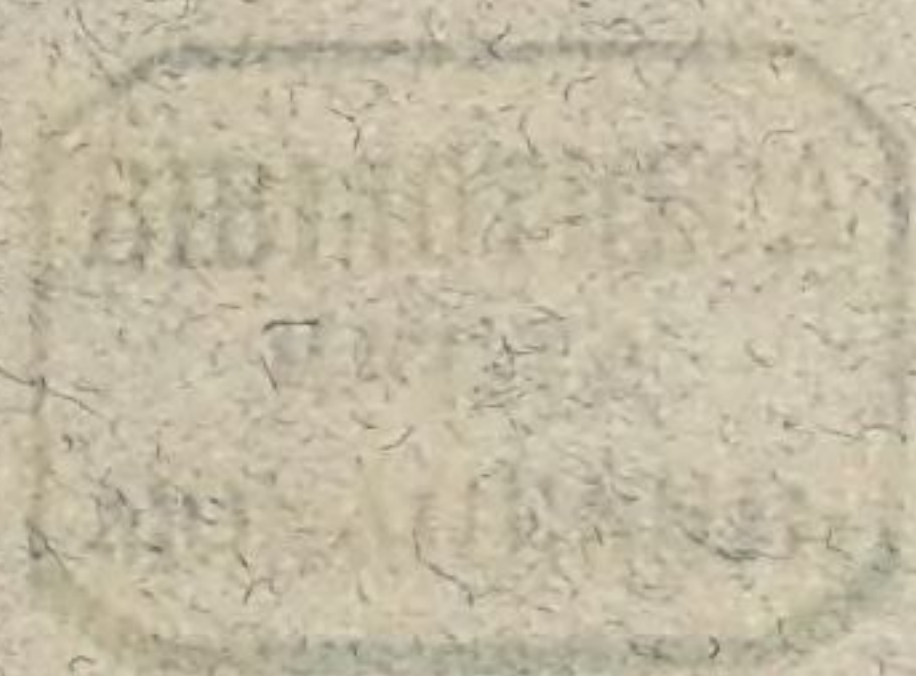
Techn.  
1440 f

Exhibit











C  
WORLD'S COLUMBIAN EXPOSITION,

CHICAGO, ILLINOIS, 1893.

---

WAR DEPARTMENT EXHIBIT.

CORPS OF ENGINEERS, U. S. ARMY.

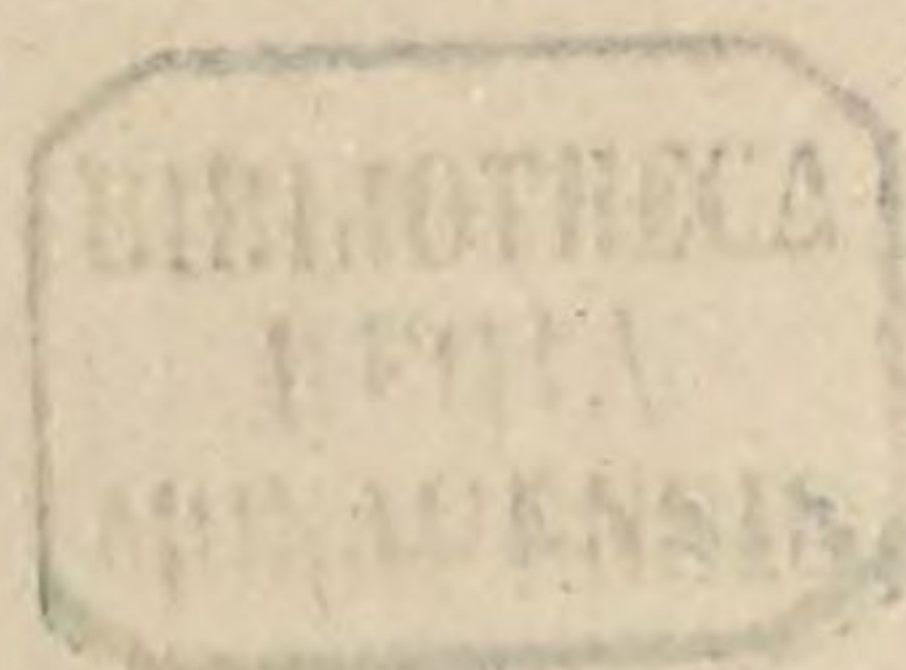
---

CATALOGUE.



WASHINGTON:  
GOVERNMENT PRINTING OFFICE.  
1893.







# TABLE OF CONTENTS.

## A.—MODELS.

### *Civil Engineering.*

|                                                                                                                                                | Page. |
|------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| Columbia River, mouth of, jetty, tramway, and plant .....                                                                                      | 5     |
| Delaware Bay. Iron pier at Lewes, Del .....                                                                                                    | 6     |
| Delaware Breakwater Harbor .....                                                                                                               | 6     |
| Delaware River. Brush and stone dike .....                                                                                                     | 7     |
| East River Improvement, New York Harbor .....                                                                                                  | 7     |
| Fox River Improvement, Wisconsin .....                                                                                                         | 14    |
| Harlem River .....                                                                                                                             | 15    |
| Hudson River, Waterford to New Baltimore .....                                                                                                 | 17    |
| James River Improvement .....                                                                                                                  | 20    |
| St. Johns River, Florida, jetty .....                                                                                                          | 23    |
| Great Kanawha River Improvement. Part of Navigation Pass, lock and dam<br>No. 6. Part of Navigation Pass, lock and dam No. 7 (full size) ..... | 24    |
| Key West Harbor, Florida .....                                                                                                                 | 25    |
| St. Marys Falls Canal Locks .....                                                                                                              | 27    |
| Mississippi River, reservoirs at headwaters of .....                                                                                           | 27    |
| Plant and Works of Construction. Improvement of the Mississippi River be-<br>tween the mouths of the Ohio and Missouri rivers .....            | 31    |
| Mississippi River, Upper. Construction of brush dam .....                                                                                      | 34    |
| New York Harbor Improvement. Model of Sandy Hook .....                                                                                         | 39    |
| Ohio River Improvement. Davis Island Dam .....                                                                                                 | 42    |
| Philadelphia Harbor .....                                                                                                                      | 46    |
| Orograph .....                                                                                                                                 | 53    |
| Zenith telescope .....                                                                                                                         | 56    |

### *Military Engineering.*

|                                                                         |    |
|-------------------------------------------------------------------------|----|
| Battery, depressing gun .....                                           | 47 |
| Battery, lift gun .....                                                 | 47 |
| Sixteen-mortar battery, Abbot's .....                                   | 48 |
| The bridge equipage. Pontoon .....                                      | 48 |
| Gun carriage, King's disappearing .....                                 | 50 |
| Gun carriage, proposed by Col. De Russy, Corps of Engineers, 1835 ..... | 50 |
| Mine, military .....                                                    | 51 |
| Mines, submarine, triple group .....                                    | 51 |
| The Sims-Edison fish torpedo .....                                      | 52 |
| Turret, Gruson .....                                                    | 53 |
| Blockhouse .....                                                        | 53 |



## B.—ENLARGED PHOTOGRAPHS, FRAMED.

|                                            | Page. |
|--------------------------------------------|-------|
| River and harbor improvements .....        | 57    |
| Military engineering .....                 | 76    |
| Light-houses .....                         | 81    |
| Public works in District of Columbia ..... | 83    |

## C.—PHOTOGRAPH ALBUMS.

|                              |    |
|------------------------------|----|
| Miscellaneous subjects ..... | 87 |
|------------------------------|----|

## D.—CHARTS, MAPS, AND DRAWINGS.

|                                     |    |
|-------------------------------------|----|
| River and harbor improvements ..... | 88 |
|-------------------------------------|----|

E.—LIST OF PUBLICATIONS OF THE ENGINEER DEPARTMENT, U. S. ARMY, INCLUDING REPORTS OF EXPLORATIONS, ETC., CONDUCTED UNDER OTHER BRANCHES OF THE WAR DEPARTMENT.

|                                                                       |     |
|-----------------------------------------------------------------------|-----|
| Professional papers of the Corps of Engineers of the U. S. Army ..... | 89  |
| Explorations and surveys .....                                        | 91  |
| Miscellaneous .....                                                   | 94  |
| Miscellaneous papers .....                                            | 97  |
| Photographic views .....                                              | 99  |
| Military maps .....                                                   | 99  |
| Topographical maps .....                                              | 101 |
| Survey of Northern and Northwestern Lakes .....                       | 103 |
| Miscellaneous maps and plans .....                                    | 103 |



# CATALOGUE OF THE ENGINEER SECTION.

---

## WAR DEPARTMENT EXHIBIT, WORLD'S COLUMBIAN EXPOSITION.

---

### A.—Models.

#### RIVER AND HARBOR IMPROVEMENTS.

1. Columbia River, mouth of, jetty, tramway, and plant. Contributed by Maj. Thomas H. Handbury.

In the progress of this work, the piles varied from 55 feet to 75 feet in length. Two jets of water were delivered at the lower end through pipes. When piles were in position in gin with hammer resting on top, pump was started and pile driven into sand 22 feet, usually in four minutes. Piles were always driven exactly to grade. Progress, 64 feet of tramway per day.

The pile-driver tender car was taken out to the pile-driver in the morning loaded with supplies for the day, 16 piles, 4 bent caps, stringers, rail bolts, etc., for 64 feet of tramway.

The inside mattresses were usually 5 feet thick and 60 feet long, made while hanging suspended from tramway stringers, dropped to water surface, and sunk with small rock. The outside mattresses were made on shore, placed upon the cars, transported out to position, and dumped on the north side of the jetty. In falling the mattress turned over before striking the water. It was hauled close alongside the inside mattress and sunk with small stones.

*Geared dump car.*—Capacity, 10 tons. The construction of these cars will permit of two men discharging a train of 20 cars in 5 minutes.

The Columbia River enters the Pacific Ocean between Cape Disappointment and Point Adams. The former is a rocky headland about 200 feet high, and the latter a low, changeable, sandy point, 6 miles distant in a south-southeast direction. Taking this line as a part of a chord, the curve of 30-foot depths (below mean lower low water) outside the bar is convex toward the sea, and its vertex about  $4\frac{1}{2}$  miles distant from this chord.

Inside the 30-foot curve the water shoals rapidly to a sandy belt, upon which, previous to the commencement of the present works of improvement, the water varied in depth from 2 or 3 to 12 or 15 feet. There were always channels across this belt whose depth sometimes reached 27 feet, but their depth and position were constantly changing. The channels varied in number from one to three, and their location through nearly 180 degrees from Cape Disappointment to Point Adams.

The growing importance of the cities of Portland and Astoria and the needs of their already extensive commerce rendered the mouth of the Columbia worthy of improvement by the General Government, and in 1882 a Board of Engineers was directed to submit a project. Accurate surveys had already been made, and from a



study of these and a comparison with all available surveys since 1792, the Board was able to gain an idea of the cause of the constant changes in the channel and to devise a scheme for preventing them. The majority of the Board reported on a plan, which was adopted by Congress in 1884; work was commenced under this project in the spring of 1885 and is now nearing completion. The object of the improvement is to provide a channel across the bar having a depth of 30 feet at the mean of the lowest low tides; its principle is to contract the current of the ebb tide into a narrower channel and to concentrate its force against a definite point of the bar; at the same time it is sought to restrict as little as possible the flow of the incoming tide. A section of the river between Point Adams and Chinook Point was found to have been constant with a depth of 40 feet for forty-one years, and the work proposed transfers in effect this section to Cape Disappointment, 6 miles further seaward. As the shore around Peacock Spit and Cape Disappointment on the north of the mouth had been persistent for many years, it was decided to locate the works of improvement on the south cape and to direct the tidal current a little north of west.

The work now in progress aims to accomplish these purposes and consists in the building of a low-tide jetty, starting from Fort Stevens, on the south cape (Point Adams), and extending in a westerly direction, slightly convex toward the north, out across Clatsop Spit for a distance of  $4\frac{1}{2}$  miles, more or less, as circumstances may require, to a point about 3 miles south of Cape Disappointment. The jetty is constructed of heavy rubble stone (basalt), resting upon a mattress foundation about 40 feet wide and from  $2\frac{1}{2}$  to 5 feet thick. The stone extends to the level of mean lower low water. The material thus far has been placed in position from a jetty tramway supported upon piles driven along the line of the jetty and about 24 feet above low-tide level. The tramway is a double track 3-foot gauge railroad, the tracks being 13 feet between centers. The material is landed at the wharf and transported to place over these tracks, which are built in advance of the main work. The effect of the jetty is already very marked in the building up of Clatsop Spit and in concentrating the waters as they flow over the bar so as to produce the desired scouring effect. In 1892 there was a straight out-and-in channel one-fourth of a mile wide and nowhere less than 29 feet deep, and for a width of 1 mile it had a depth of 27 feet.

The annual registered tonnage across the bar in 1882 was 422,306 tons; in 1884 1,417,901 tons; in 1892 2,019,467 tons.

## 2. Delaware Bay. Iron pier at Lewes, Delaware. Contributed by Maj. C. W. Raymond.

This pier is situated on the south side of the entrance of Delaware bay, and is maintained for the convenience of vessels frequenting the Breakwater harbor, and for the Government service. It was constructed between 1871 and 1880. The length of the pier is 1,701 feet. The model shows two bays of the head and one bay of the bridge on a scale of 1 foot to 1 inch, and it is accompanied by a model of the derrick used in construction, on a scale of 1 foot to 1 inch. These models were exhibited at the Centennial Exposition at Philadelphia in 1876.

## 3. Delaware Breakwater Harbor. Contributed by Maj. C. W. Raymond.

The harbor is situated on the south side of the entrance to Delaware Bay, near Cape Henlopen. The construction of the breakwaters was commenced in 1828 and is still in progress. The model shows the breakwater, the harbor, and the adjacent shore, on a horizontal scale of 100 feet to 1 inch and a vertical scale of 18 feet to 1 inch. The accompanying small models show the typical cross sections of the east, west, and middle sections of the breakwater.



4. Delaware Breakwater Harbor. Model of stone barge of the Brandywine Granite Company used in the construction of the Delaware Breakwater, with specimens of stone. Contributed by Maj. C. W. Raymond.

5. Delaware River. Brush and stone dike. Contributed by Maj. C. W. Raymond.

A low-water dike was constructed on this plan at the lower end of Reedy Island, 45 miles below Philadelphia, in 1889. As the bottom is soft mud to a great depth, it was necessary to employ a combination of brush and stone to reduce the weight on the foundation as much as possible. The length of the dike is 6,000 feet. The model shows the details of construction on a scale of 2 feet to 1 inch:

6. Delaware River. Pile and stone dike. Contributed by Maj. C. W. Raymond.

Dikes of this type have been constructed at Fishers Point, at the upper end of the port of Philadelphia, in 1890, and at Bulkhead Bar, 35 miles below Philadelphia, in 1892. The Bulkhead Bar dike is 4,000 feet in length. The model shows the details of construction on a scale of 4 feet to 1 inch.

7. Delaware River. Stone dike with single mattress. Contributed by Maj. C. W. Raymond.

The low-water dike built on this plan at Mifflin Bar, 10 miles below Philadelphia, was completed in 1888 and has a length of 7,300 feet. A portion of the dike at Fishers Point, at the upper end of the port of Philadelphia, was built on this plan in 1886, but was raised above high water in 1890. The model shows the details of construction on a scale of 2 feet to 1 inch.

8. Delaware River. Ice pier at Marcus Hook. Contributed by Maj. C. W. Raymond.

The harbor is situated on the right bank of the Delaware River, about 20 miles below Philadelphia. It contains seven ice piers. The model shows the details of construction of a pier on a scale of 4 feet to 1 inch.

East River Improvement, New York Harbor. Models contributed by Lieut. Col. G. L. Gillespie, Corps of Engineers, in charge.

9. Hallets Point.
10. Part of mine at Flood Rock.
11. Drill scow "Gen. John Newton."
12. Hell Gate.
13. Ways Reef, Hell Gate.

The following history of the East River improvement has been furnished by Col. Gillespie:

#### IMPROVEMENT OF EAST RIVER AND HELL GATE, NEW YORK.

The East River is the name given to the narrow tidal strait which connects New York Harbor with Long Island Sound. It forms an entrance to the harbor of New York secondary in importance only to the main entrance by way of Sandy Hook and the Narrows, since the heavy coasting trade carried on by New York with the New England States and the British American Provinces passes almost exclusively through it.

The East River is crooked and narrow in places, and much obstructed by rocks, and affected by violent currents.



The worst of these obstructions is that known as Hell Gate, lying at the mouth of the Harlem River, between Blackwells and Ward islands, about opposite Ninety-sixth street, New York. Here the river turns at right angles around Hallets Point, divides into several channels, and runs with a velocity varying at different stages of the tide from 3 to 10 miles an hour, over or around Hallets Point, Negro Point, Ways Reef, Shell Drake, Pot Rock, Frying Pan, Heel Tap, Holmes Rock, Hog Back, Flood Rock, Hen and Chickens, Gridiron, The Negro Heads, Mill Rocks, Rhineland Reef, and Bread and Cheese.

On account of the violence and irregularities of the currents and the crowded condition of this passage, wrecks at Hell Gate were numerous prior to 1867. At that time some of these rocks projected above the water level, while the least depth over others, at mean low water, varied from nothing to 20 feet. In obedience to the provisions of the act approved June 23, 1866, an examination was made of Hell Gate by the local engineer with a view of its improvement for purposes of navigation, and three separate projects were submitted January 21, 1867, affording channels of 26 and 24 feet in depth at mean low water.

The plan which was adopted in 1867 provided for the removal to a depth of 26 feet at mean low water of the rocks and reefs before mentioned, lying directly in the channel, and for the building of sea-walls and dikes upon others lying near the edge of the channel, in order to guide the currents in a direction favorable for the safe navigation of vessels past the reefs. The cost of the project was estimated at \$8,692,645.15.

Prior to 1867 attempts at the removal of obstructive reefs in the East River were made solely by the ignition of large charges of explosives placed directly upon the upper surface of the rock, or within cavities favorable for developing the disruptive energy of the explosive.

The meager results of this method led to the formation of plans for attacking the reefs by sinking vertical shafts through them, from the bottom of which galleries were to be excavated, running in all directions beneath the overlying reef. In these galleries numerous mines were placed, whose simultaneous explosion by electricity was designed to disrupt and shatter the reef at a single blast. This method was satisfactorily applied in the removal of Hallets Point in 1869-'76, and of Flood Rock in 1875-'85.

While these latter plans were in progress a steam-drill scow was devised for effecting less extensive operations of rock removal.

It consisted of a staunch floating scow, with an open well in the center, within which a movable dome of wrought iron was worked, whose principal function was to protect the drills when in operation against violent action of swift currents.

It has been in use since 1870, and has afforded means for removing submarine rock at economical rates.

*Hallets Point removal.*—The removal of Hallets Point, by mining, was begun in 1869, and the final blast occurred September 24, 1876.

The following is a brief description of the operations for its removal prepared by General Newton, the engineer officer then in charge:

“This reef projects into the channel at Hell Gate about 300 feet. The depth over it for a distance of 270 feet from the shore is, at low water, less than 12 feet. The channel here being narrow and crooked, the object of this improvement is to widen and straighten it by securing a least depth of 26 feet over the reef.

“Work was commenced in July, 1869, by building a cofferdam between high and low water marks. In October following the excavation of the shaft was begun. From the bottom of the shaft ten tunnels were driven under the river in radial lines, and were extended until a depth of water upon the reef of 26 feet at low tide was reached; the roof of the excavation being kept nearly parallel to the bed of



the river and about 10 feet below it. The main tunnels are about 14 feet in width, varying from 10 to 22 feet in height, and averaging about 270 feet in length. They are connected with each other at intervals of 30 feet by means of cross tunnels or galleries of about the same height and width. Between the tunnels and galleries large columns of solid rock were left to support the roof of the excavation or bed of the river. These large columns were afterwards cut through by other tunnels and galleries until finally one hundred and seventy-three piers were formed, averaging about 10 feet each in thickness. The entire reef, covering an area of 3 acres, is thus undermined. The aggregate length of tunnels and galleries driven under the bed of the river is 7,425 feet. From the excavation 47,461 cubic yards of rock have been removed by drilling and blasting. This operation required 208,174 linear feet of drill holes, of which 90,107 feet in depth were drilled by hand and 118,067 feet by various kinds of machine drills, viz, the Burleigh, Diamond, Rand, Winchester, Wood, Ingersoll, and Waring drills, worked by compressed air.

"The following quantities and kinds of explosives were used in blasting the rocks :

|                       | Pounds. |
|-----------------------|---------|
| Blasting powder ..... | 24, 431 |
| Nitroglycerine .....  | 26, 471 |
| Giant powder .....    | 1, 932  |
| Mica powder .....     | 600     |
| Vulcan powder .....   | 4, 017  |
| Rendrock .....        | 1, 500  |

"In exploding these compounds 63,756 exploders and 331,516 feet of Bickford's safety fuse were used. In all, about 75,000 blasts were fired. The usual method of driving a tunnel was as follows : The face of the rock was pierced obliquely with as many drill holes, from 3 to 4 feet in depth, as were deemed necessary ; the charges were then prepared by placing the explosive in water-tight paper cartridges, from 8 to 12 inches long and containing from 8 to 12 ounces of explosive ; into each of these cartridges would be inserted a copper cap (containing mercury fulminate) fastened to the end of a piece of safety fuse, generally about 5 feet in length. The cartridge was then pushed to the bottom of each hole, which was filled with water. The ends of the fuses hanging from the drill holes were then ignited. The broken rock was then loaded upon small cars carrying about one-third of a cubic yard each, which were hauled by mules along a railway to a turntable near the middle of the floor of the shaft, where a derrick worked by steam hoisted the car body and its contents off the truck to the top of the shaft, and the rock there dumped into a tipping car attached to a small steam locomotive, which conveyed the débris and deposited them at the end of the dump pile."

The excavations by headings were completed in June, 1875. The work of drilling holes in the roof and piers was begun in June, 1875, and completed March 25, 1876. There had then been drilled in the roof 5,375 3-inch holes, and in the piers 1,080 3-inch and 286 2-inch holes ; aggregating 56,548 feet of 3-inch and 1,897 feet of 2-inch holes.

The cubic contents of the roof and piers were 63,135 cubic yards, and the quantity of explosives used was as follows :

|                     | Pounds.                |
|---------------------|------------------------|
| Rendrock .....      | 9, 127 $\frac{1}{2}$   |
| Vulcan powder ..... | 11, 852 $\frac{3}{8}$  |
| Dynamite .....      | 28, 935 $\frac{1}{4}$  |
| Total .....         | 49, 915 $\frac{9}{16}$ |

This was at the rate of 0.79 pound of explosive to each cubic yard of rock.



The explosives were packed at the respective places of manufacture in tin cartridge cases, furnished by the Government.

The number of holes charged was 4,427, and the number of tins used was 13,396—87 per cent being 22 inches in length and the remainder 11 inches.

As the holes tapered from top to bottom, the cases varied in diameter from  $1\frac{3}{8}$  inches to  $2\frac{1}{2}$  inches, the intermediate sizes differing by one-eighth of an inch.

The charging of holes was commenced on the 11th of September, 1876, and finished at 9 p. m. on the 20th, consuming nine days.

After the holes had been charged, priming charges in brass tubes were inserted, the quantity of which—three-fourths of a pound to each primer—has been included in the total already given. The primers contained also, as detonators, fuses holding each 20 grains of fulminate of mercury. The terminals of two connecting wires were inserted in each fuse, and bridged with 1.0015 inch silver platinum wires, one-fourth inch in length. The fuses, in groups of twenty, were connected in continuous series with connecting wires. A lead and return wire were attached to each group. Twenty primers, with fuses and wires properly arranged in a box, with lead and return wires on reels, were carried to each party engaged in this work. The time consumed in placing 3,680 primers, unreeling the lead and return wires, and leading these out of the shaft was two and one-half days.

The batteries used consisted respectively of 40, 43, and 44 cells of zinc and carbon, or 960 cells in all, divided into 23 distinct batteries, each battery to fire 160 fuses, arranged in divided circuit in eight groups of 20 each. The mines of each group were connected in continuous series, and a lead and return wire to the battery closed the circuit. The whole system was discharged by means of a "circuit closer," which was so arranged as to close all the circuits at the same instant. The mines were fired at 2:50 p. m. on September 24, 1876, and the explosion was distinguished by the absence of hurtful shocks in the atmosphere, in the water, or under ground. The broken rock resulting from the explosion was subsequently removed to a depth of 26 feet at mean low water, under various contracts extending from 1876 to 1882. The total quantity of broken stone removed was 90,588 gross tons, at a total cost of \$282,295.83.

The amount expended for excavation and explosion at Hallets Point was \$952,105.77, and the total cost of completion was \$1,234,401.60.

A new estimate for the entire river was made January 3, 1870, "based upon the process of tunneling Hallets Point and removing the smaller reefs by drilling from the surface of the water," and the cost was placed at \$4,689,820.

The estimate was again revised in 1874 to include the removal of Diamond and Coenties reefs, and the total cost fixed at \$5,139,120.

*Steam-drilling scow.*—The removal of the smaller reefs by operations conducted from the surface of the water was effected by a steam-drilling scow, which was first put in commission in the winter of 1870-'71.

Gen. John Newton, the engineer officer then in charge, describes it and its method of operation as follows:

"This machine consists of two parts—a large float or scow, having a well-hole in it of a diameter of 32 feet. It is built very heavy and strong, and is provided with an overhang or guard around it, faced with iron, and has proved itself, up to this time, capable of withstanding violent collisions with other vessels. Besides affording this security, it serves also to transport the caisson or dome from place to place, and is a working platform from which the drilling engines are operated. The caisson or dome is a hemisphere, of the diameter of 30 feet, composed of a strong iron frame covered with boiler iron. The dome is open at bottom and at top, and is provided at the bottom with legs to support and level it, which are arranged to let go all together after the dome is lowered. Owing to the hemispherical shape of



the caisson, the pressures of the moving mass of water, which are normal to the surface, necessarily pass through the center, and there is consequently no tendency to an overthrow by the action of horizontal currents, but, on the contrary, an additional pressure favorable to stability is produced.

"The caisson or dome is simply a framework, affording a fixed support to twenty-one drill-tubes through which the drills operate. The dome is connected with the scow by four chains, communicating with four hoisting engines, by which it is lowered or raised. A framework is built upon the scow around the well-hole to support the carriage holding the drill engines, which by these means may be placed directly over the drill-tubes. The engines simply raise the drill-rods and allow them to fall by their weight upon the rocks, the vertical play being 18 inches. The drill and drill-rods together are about 10 feet long, and weigh from 600 to 700 pounds. The cutting edges are in the form of a cross, and are  $5\frac{1}{2}$  inches long.

"The scow, having the dome swung by chains, is first anchored over the rock to be operated upon, so that the bow and aft moorings pull against the direct currents of the ebb and flood tides; but as these may vary somewhat in direction from one tide to another, as well as during the course of the same tide, it becomes necessary, in order to steady the scow, to have side anchors also. The diver descends to ascertain whether the location is well suited to placing the dome on the bottom, and if not, to select a better. The required change in the position of the scow is made by lengthening and shortening the mooring chains with capstans, which are arranged to be worked at will with steam or man power. The dome is then lowered and when it touches or approaches near the bottom the legs are let go by the run, and, being held by self-acting cams, support the weight of the dome. The chains are now unslung from the dome, which is thereby without connection with the scow. The diver descends to ascertain which of the drill-tubes it is necessary to use to break up the rock within the dome, and how the surface offers itself to each particular drill. The drill-rods being introduced within the drill-tubes, which is easily effected during the most violent currents, a rope or other flexible connection is now made between the top of the drill-rod and the piston-rod of the drilling engines. A flexible connection is necessary to the act of drilling, as in this machine, the dome remaining fixed upon the bottom in one position, while the scow holding the drill engines swings for short distances from changes in the direction and strength of the currents, no rigid connection between the engine and drills would be practicable. The length of the rope attachment is regulated by a feed-gear for the rise and fall of the tides and continual changes of water level.

"The drilling being completed, preparations are made for charging the holes with explosive. The chains are hooked on the dome, which is then raised from the bottom, and the scow swung off from the spot to a safe distance without casting loose the moorings. This distance will depend upon the proposed amount of charge of explosive, and will vary from 175 to 300 feet. The explosive, in tin cases of different lengths to suit the varying depths of the drill holes, is carried to the spot upon a small scow, from which the diver descends to the first hole to be charged. He is guided in this by a line. Withdrawing the plug he introduces into the hole the tin cartridge, which has been filled by the men on the scow and passed down to him. Each cartridge is attached, before it is sent down, to the wires. The diver then passes on to the second hole, guided by the plug line which connects the stoppers of the adjacent holes, and in this way the whole circuit of holes is visited and charged. The leading wires are connected with the battery when the small scow has been withdrawn, and the explosion is made.

"To break up the rock thoroughly the drill holes should be from 6 to 8 feet apart of the size of  $5\frac{1}{2}$  inches at top, with the usual tapering towards the bottom, and charged with amounts varying with the depths of hole, which will average between



50 and 60 pounds for each. Under these conditions the depth to which the drill hole reached below the level to which it was desired to break the rock was about 4 feet.

"After the rock broken by the explosion covers the greater part of the reef, its removal is commenced. This is effected by means of a steam grapple."

By the above described machine Ways Reef, Shell Drake, and North Brothers Island Reef, in Hell Gate; and Diamond Reef, Coenties Reef, reef off Diamond Reef, and Pilgrim Rock, in East River, have been removed. It has also operated upon Frying Pan, Pot Rock, and Heel Tap Rock, in Hell Gate; and Ferry Reef, in East River; Baxters Ledge, in New York Harbor; Corning Rock, in New Rochelle Harbor, and upon a channel through a reef in the Harlem River.

*Flood Rock removal.*—The work embraced in this improvement, measuring an area of 9 acres, consisted of the whole of the Middle Reef in Hell Gate, comprising Flood Rock proper and the secondary reefs known as The Negro Heads, Gridiron, and Hen and Chickens. A narrow strip of Flood Rock was bare at high water, and isolated projections of other reefs mentioned were visible at low water. The present project of improvement contemplates making a depth of 26 feet over the entire area of this reef.

The method adopted was similar to that followed at Hallets Point, and consisted in sinking a shaft from the highest point of Flood Rock down to the grade of 65 feet below the plane of mean low water, and running galleries from the plane of 45 feet below mean low water under the whole reef in such a way that a single blast would break up the entire mass in shapes convenient for removal.

The total amount expended upon Flood Rock from June 7, 1875, when the sinking of the shaft was begun, to October 12, 1885, when all hands were paid off, was \$1,061,983.18.

The following table shows, in general, the amount of work done:

|                                                                                 |          |
|---------------------------------------------------------------------------------|----------|
| Number of feet of galleries driven .....                                        | 21, 669  |
| Number of cubic yards of rock mined .....                                       | 80, 232  |
| Number of 2-inch holes drilled .....                                            | 235, 318 |
| Number of feet of 2-inch holes drilled .....                                    | 974, 446 |
| Number of pounds of explosive used in mining (principally dynamite No. 2) ..... | 84, 407  |
| Number of 3-inch holes drilled for final blast .....                            | 13, 023  |
| Number of feet of 3-inch holes drilled .....                                    | 113, 102 |
| Number of cubic yards of rock broken by final blast .....                       | 270, 716 |

The cost of running subaqueous tunnels with the top of the arch only a few feet below the bed of the stream is ordinarily greater when the rock to be penetrated is treacherous and seamy than when it is solid and compact. In the former case water penetrates into the chambers, delaying operations and causing additional expense for tamping and bulkheading weak spots. The working methods followed at Hallets Point and Flood Rock were very similar, but the experience gained by the work at the former locality enabled the engineer to reduce the cost of work at the latter. This reduction is the more noticeable as the rock strata at Hallets Point were uniformly regular and compact, while at Flood Rock they were in many places irregular and seamy.

The sinking of the shaft at Flood Rock was begun June 7, 1875, and the excavations of the whole mine could have been finished in four years had sufficient appropriations been available, but owing to frequent enforced suspensions of work arising from exhaustion of funds the mine was not completed till June, 1885.

Preparations began June 30, 1885, for loading into the mine the 288,936 pounds of explosive required for the blast, and the charging was completed September 28. The aggregate charges consisted of 240,399 pounds of rackarock and 42,331 pounds of dynamite.



mite, No. 1. The rackarock was placed in copper cartridges 2 feet long and  $2\frac{1}{2}$  inches in diameter, made of sheet copper only 0.005 inch thick and tinned on the inside. These cartridges, of which 44,175 were used, contained each about 6 pounds of the explosive. In addition a small primer, consisting of a 30-grain fulminate cap and 1 ounce of No. 1 dynamite put loosely into a stout copper shell, tightly corked and sealed, was buried in the rackarock about 4 inches from the end of the can. The office of this primer was to transmit the explosion throughout the length of the charge in the drill holes, which, in many cases, were as much as 12 feet deep.

The other cartridges, of which 14,162 were used, were  $2\frac{1}{4}$  inches in diameter and 15 inches long and contained about 3 pounds of No. 1 dynamite. A 30-grain fulminate cap was inserted in each cartridge with the object of insuring an explosion of the first order when the charge was fired by sympathy. In all cases the last cartridge put in each hole was one of dynamite, and the end of the cartridge was allowed to project from the hole a distance of about 6 inches.

The explosion was distributed over the whole 9 acres of the reef in proportion of the volume of rock increased by one-fourth of the volume of water overhead. Where the rock was very hard an increase of 25 per cent was made, but where exceptionally soft a reduction of 25 per cent was made. The computed number of cubic yards of rock to be broken by the blast was 270,716, and the charge was fixed at the rate of 1.04 pounds of the explosive per cubic yard of rock.

The charge at the final blast at Hallets Point in 1876 was 0.79 pound per cubic yard, but an increase was deemed necessary at Flood Rock because the greater thickness of the roof made it expedient; because the amount of rock excavated from the galleries was 2.7 times less than at Hallets Point, and consequently the whole of the reef had to be lifted to allow it to break, instead of getting the breaking effect of a fall, as at Hallets Point.

The charges of the two explosives, aggregating 282,730 pounds, were distributed in 12,561 drill holes, of which the average charge was 22.5 pounds, and the maximum charge 37 pounds.

The arrangements for firing simultaneously this large number of charges were reduced to great simplicity. It having been ascertained by elaborate experiments that the explosion of a charge of 10 pounds of dynamite under water will fire with certainty any number of other charges of dynamite, packed solidly in their elastic envelopes, within a radius of 27 feet, primary charges of 10 pounds of dynamite were placed at intervals of 25 feet along the galleries from which the holes were drilled, and these primary charges only were connected with the batteries. They numbered 591, arranged on 24 different circuits. In locating the primary charges care was taken to have alternate charges on different circuits, so that in the event of a failure of any circuit its charges would nevertheless explode by sympathy, being within less than 27 feet of four other primaries on three other circuits. Twenty-one of the circuits contained 25 fuses, each connected with wires 52 feet long, of No. 18 copper, insulated to No. 9, with leading wires at the end of each circuit 600 feet long, of No. 12 copper, insulated to No. 9 A wire gauge. The remaining three circuits contained 22 fuses, each connected with wires 106 feet long, and having leading wires of 950 feet; these circuits, intended for the extreme northern portion of the work were nearly a mile in length.

The battery used in firing the mine consisted of 60 bichromate cells, coupled in series. The plates were 6 inches by 9 inches, four carbon and three zinc in each cell, separated by only one-fourth of an inch. The battery was of sufficient power to send through every fuse a current just double that computed to be necessary to fire it.

The mine was fired from a point on the Astoria shore, about 1,000 feet away, at 11 hours 13 minutes and 50 seconds standard time, October 10, 1885.



Three instantaneous photographs were taken at different periods of the upheaval. The first of these, taken two-tenths of a second after the closing of the circuit, shows the water rising nearly uniformly over the whole site of the reef, and illustrates well both the completeness of the explosion and the simultaneity of the action of the separate charges. As was expected, there was no loud report, no severe shock through the earth, and no scattering of the débris.

A survey of the reef made immediately after the explosion showed that the surface of the whole reef had been altered, proving the reef to be shattered, and the changes were nowhere greater than at the remotest corner of the reef, where the bottom had been raised 10 feet.

It is estimated that the total amount of broken rock required to be removed to give a clear depth of 26 feet at mean low water over the whole reef is 294,000 tons. At the close of the fiscal year ending June 30, 1892, there had been removed 177,376 tons under contract and by hired labor. Since June 25, 1889, work of raising broken stone has been carried on by hired labor, using Government plant consisting of two powerful grapple dredges.

On the complete removal of Flood Rock, expected in 1894, the navigable channel through Hell Gate will be 1,000 feet wide, and 26 feet deep at mean low water.

The project was enlarged in 1884 to include the removal of Pilgrim rock, off Nineteenth street, to 24 feet, mean low water; in 1889 to include the removal of the reef off Diamond Reef, Ferry Reef, off Thirty-fourth street, and Charlotte Rock, northwest of entrance to Newton Creek, to 26 feet, mean low water; in 1890 to include the removal of Shell Reef, opposite Ninth street, New York City, and Middle Ground, off Sunken Meadow, to a depth of 18 feet, mean low water; and in 1892 to include the removal of reef off Baretto Point to a depth of 26 feet, mean low water. No change has been made in the estimate of cost, which remains at \$5,139,120.

At the close of the fiscal year ending June 30, 1892, the sum of \$4,057,330 had been expended upon the project; of this sum \$1,234,401 had been applied at Hallets Point, \$1,488,157 at Flood Rock, and \$1,334,772 at other obstructions in the river.

The following parts of the project have been executed: Hallets Point, covering 3 acres; Ways Reef, Shell Drake, Diamond Reef, North Brothers Island Reef, Coenties Rock, Scaly Rock, and reef off Diamond Reef have been removed to the depth of 26 feet, mean low water; Pilgrim Rock and Ferry Reef have been reduced to a least depth of 24 feet; Heel Tap has been broken to 26 feet and dredged to 20.5 feet, and the least depths on Frying Pan and Pot Rock are 18 and 22.8 feet, respectively; Flood Rock and connecting reefs, covering 9 acres, have been broken to 30 feet, and 177,375 tons of the débris removed. A channel 530 feet wide and 18 feet deep, mean low water, has been dredged across Shell Reef from Eighth street to Twelfth street.

#### 14. Fox River Improvement, Wisconsin. Sluice gates of lower dam at Appleton. Contributed by Maj. J. F. Gregory.

The model is made to a scale of 1 inch to 1 foot, and represents a section of the lower dam at Appleton, Wis., which was built by the United States in 1888-'89, for improving the navigation of Lower Fox River. The dam is of cribwork filled with stone; the abutments of dam and piers between the sluiceways are of dressed stone laid in cement mortar. There are five sluiceways in the dam for the purpose of regulating the stage of water in the pool above the dam, each sluiceway being 20 feet in width and 7 feet 4 inches in depth below crest of dam. The sluiceways are provided with wooden gates of the Taintor style, which, by means of the winch, can be easily opened or closed by one man. The dam rests on the rock bed of the river, is 410 feet in length (exclusive of the sluiceways), 8 feet 4 inches in height, and has a cross-section width of 24 feet, including the apron, 8 feet wide.



Whenever a gate is to be opened the winch is placed at the gate, the pinion between the large gear wheels disengaged and sufficient chain unwound from the drums to allow of the hooking of the drum chains to the gate chains; the pinion is then placed in gear with the spur wheels and the gate raised to the desired height. To hold the gate in place after it has been opened a forked iron is placed on one of the links of the gate chains and allowed to rest upon the platform underneath the winch; the drum chains of the winch are then unhooked from the gate chain and the winch moved to the next gate to be opened.

15. Fox River Improvement, Wisconsin. Section of upper dam at Appleton. Contributed by Maj. J. F. Gregory.

The model is made to a scale of 1 inch to 1 foot, and represents an abutment and section of the upper dam at Appleton, Wis., built by the United States in 1873-'74, for the improvement of navigation of the Lower Fox River.

The dam is built of dressed stone laid in cement mortar; is 699 feet in length (including five sluiceways, each 20 feet in width), and 9 feet in height.

16. Fox River Improvement, Wisconsin. Stone lock at Appleton. Contributed by Maj. J. F. Gregory.

The model is made to a scale of half an inch to 1 foot, and represents one of the locks built by the United States to improve the navigation of the Lower Fox River, Wisconsin. This river is an outlet of Lake Winnebago, Wisconsin, whose surface is 170 feet above the level of Green Bay, an arm of Lake Michigan, into which the river empties.

The waters of the river descend with great rapidity over a bed of limestone rock, forming numerous rapids. For the purpose of improving the navigation of the river, dams were built at these rapids, converting the channel of the river into series of deep-water reaches. In a side cut or canal, near the end of a dam, a lock is provided by means of which boats are raised or lowered from one reach of the river to another. In case a boat wishes to pass from a lower to a higher reach of the river she enters the lock at the lower gates; the gates and the valves in the gates are then closed, and the valves in the bulkhead at one of the upper gate recesses are opened and the lock rapidly fills with water, the boat being gradually raised by the water as it fills the lock; when the water in the lock comes to a level with that in the reach of the river above the lock, the upper gates are opened and the boat passes out of the lock. In passing a boat from an upper to a lower reach of the river a contrary operation is gone through with. The time required to pass a boat through a lock is from seven to ten minutes.

The locks are generally built of dressed stone masonry, and have a capacity to pass boats 34 feet beam, 144 feet in length, and a draft of 6 feet of water.

17. Harlem River. Contributed by Lieut. Col. G. L. Gillespie.

IMPROVEMENT OF THE HARLEM RIVER, NEW YORK.

The streams embraced in this improvement are the Harlem River, which empties into the East River near Hell Gate, and the Spuyten Duyvil Creek, which empties into the Hudson River about 13 miles north of its mouth, the two separating Manhattan Island from the mainland. They are both tidal inlets, connecting freely at their mouths with important tidal avenues.

There has always been a water connection between the headwaters of the two streams, but a long ledge of rocks awash at mean low water, together with an extremely narrow channel at Kingsbridge, has prohibited its use for commercial purposes.



The head of navigation in the Harlem River, at low tide, was originally at High-Bridge, 5 miles from the East River at Hell Gate, for vessels drawing 7 feet; and to Spuyten Duyvil, near Kingsbridge, at high tide, for vessels drawing 8 feet.

The range of tides in the Harlem near Kingsbridge is 6 feet, and in the Spuyten Duyvil 3.8 feet.

Tidal observations have shown that there is not a free exchange of tides between the two streams, but that there is practically a divide near Fordham bridge between the tides flowing from the East River into the Harlem, and from the Hudson River into Spuyten Duyvil Creek. Comparing the tides of the Harlem River with those of the Hudson River at the mouth of the Spuyten Duyvil Creek, it has been found—

(1) That the level of mean high water in the Hudson is nearly 1 foot (0.961) lower than it is in the Harlem.

(2) That the mean rise and fall of the tide in the Hudson is 2.12 feet less than it is in the Harlem.

(3) That the mean duration of the rise of tides in the Hudson is 36 minutes shorter, and the mean duration of the fall 26 minutes longer than in the Harlem.

(4) That the mean level of the Hudson at the mouth of Spuyten Duyvil Creek is 0.265 of a foot lower than at Fordham bridge.

(5) That high water occurs 1 hour and 34 minutes earlier in the Hudson than in the Harlem.

In compliance with an act of Congress a survey was made in 1874 with the view of preparing an estimate of cost for opening a navigable water connection between the East River and the Hudson River, following the line of the Harlem River, and a project based upon the results then determined was adopted in 1875, which provided for a waterway everywhere 400 feet wide and 15 feet deep at mean low water, except in the artificial channel to be excavated through rock along Dyckman Creek, connecting the headwaters of the two streams, where the width was reduced to 350 feet, and the depth increased to 18 feet.

The estimated cost was \$2,700,000, including \$600,000 for removing obstructions in the eastern or lower reach of the Harlem River.

It follows from a study of tidal conditions that, while on the opening of the new channel through Dyckman Meadow there will be a free flow east or west, dependent upon the stage of the tides, the preponderance will be westward, and that the mouth of the improved channel will then be at the junction with the Hudson River.

As the tidal currents are relied upon to maintain the improvement, the channel cross sections are made as nearly uniform as possible, in order to avoid unnecessary resistances to water flow. Additional provision against undue head in the Harlem River is made by leaving open the natural channel passing Kingsbridge.

Work under the project, which was begun in 1888 by contract, as the law requires, by building two earthen and stone dams across Dyckman Creek, 1,200 feet apart, preparatory to the removal of the inclosed rock, after drilling and blasting by ordinary methods, has continued since that date without interruption.

The projected channel at this point has been completed, and the banks protected by stone and timber revetment walls, and the contiguous streams on either side have been dredged to within a few hundred feet of the dams, so that when the latter are removed, in November, 1893, there will be a free and navigable channel between the Hudson River and the East River, with a least width of 150 feet and a least depth of 9 feet at mean low water, or 15 feet at mean high water. Thereafter these channel dimensions will be increased proportionately with additional appropriations until the project is completed.

North of Morris Heights the banks of the Harlem River, as far as the entrance to the artificial cut at Dyckman Creek, are comparatively high, though the margins of the stream are flat and marshy, and the latter, like the bed, are composed of



alluvium in which is incorporated decayed vegetable matter assimilated to peat. The material is very soft and deep, and it is thought the new banks will be easily eroded by currents, if not protected by suitable revetments.

No plans for revetment have been formed, except for that absolutely required to preserve the slopes of the artificial cut along Dyckman Creek, consisting partly of stone walls and partly of timber work.

Rock outcrops above the plane of 15 feet below mean low water at several points in the Harlem River between Morris Heights and the East River, and occasionally groups of large boulders overlie the bed, but in general the bed is composed of mud with an admixture of sand, and the banks are high and stable.

The excavated material, so far as the improvement has progressed, has either been used to fill up adjacent lowlands, protected by secure bulkheads, or has been towed to sea beyond the Sandy Hook bar, a distance of 30 miles, approximately.

The bed of the improved channel near the head waters of Spuyten Duyvil Creek is soft alluvium and the banks are low and marshy, but near the Hudson River the bed is of loam, clay, and sand, and the banks are high, rocky, and stable.

Neither of the streams has a freshet rise due to rainfall.

The bridges spanning the combined waterways are required by law to have their lower chords placed at the least height of 24 feet above high water of spring tides, and to be provided with two contiguous draw-openings, each 100 feet wide in the clear, situated on either side of a pivot pier 40 feet in diameter.

18. Hudson River, Waterford to New Baltimore. Contributed by  
Lieut. Col. G. L. Gillespie.

#### IMPROVEMENT OF THE HUDSON RIVER, NEW YORK.

The Hudson River has its source in fourteen small lakes in the Adirondack Mountains of northern New York, 200 feet above tide water, with an aggregate water area of 6,000 acres. The total drainage area from the source to Troy, N. Y., a distance of 125 miles, including that of the Mohawk River, its principal tributary, is 7,200 square miles.

The State dam at Troy, the dividing line between the tidal and nontidal compartments of the river system, has a lock on the east bank, extending navigation by slack water to Waterford and beyond.

The Erie Canal and its Oswego branch, with a least depth of 7 feet, connects the Northwestern Lakes with the Hudson River at Albany; the Champlain Canal, 7 feet depth, connects the St Lawrence River with the Hudson River at Waterford, and also at Albany by connection with the Erie Canal; and the Delaware and Hudson Canal, 6 feet depth, connects the Delaware River with the Hudson River at Rondout, N. Y.

During the year 1890 the freight coming to and leaving the Hudson River through the State canals was 3,600,000 tons, and the total tonnage of the Hudson River for the same period was 18,500,000 tons.

The mean range of tides at Albany is 2.32 feet, and at the State dam at Troy 0.80 feet.

From February to July, and from October to close of navigation in each year, the river has ordinarily a freshet rise varying from 2 feet to 5 feet, which correspondingly increases navigable facilities during these periods.

Below the city of Hudson the river has always had channel dimensions for convenient navigation by vessels drawing 20 feet, but originally the navigable depth to Albany was limited to  $7\frac{1}{2}$  feet at mean low water, and 4 feet to Troy.



The obstructions to navigation in the Hudson River consist of numerous sand and gravel bars and of rocky reefs. The bars from the State dam at Troy to Van Wies Point are composed of small gravel and coarse sand, the bed of the deep holes of the intervening pools having occasionally a covering of boulders, and thence to New Baltimore and below the bars are composed of fine sand.

The rock reefs which cross the main channel and seriously obstruct navigation are all found in the upper river in the vicinity of Troy.

Instances of isolated rocks in the main channel are found below Albany in immediate proximity to Van Wies Point, and just below New Baltimore. The original depth of water above rock formation varied from 8 feet to 17 feet at mean low water.

The rock is of a schistose formation, having a pronounced slaty structure. Sometimes it appears in very hard masses, and when blasted breaks into fragments of convenient size for easy removal; and again, it is soft and friable, making its removal difficult either by the dredger or by blasting.

As the result of improvements made jointly by the State of New York and by the United States, the river has a present navigable depth of not less than 20 feet at mean low water, from its mouth at New York City northward to Hudson City, 110 miles; 10 feet to Albany, 146 miles; and 8 feet to 9 feet to Troy, 152 miles. Above Troy, slack-water navigation obtains, and commerce is carried in canal boats.

River improvement by the State authorities antedates the present century, but the part taken in it by the General Government dates only from 1834. The plan of improvement originally followed by the State, providing for the application of groins or jetties for contracting the channel to induce scour, was modified in 1834 to conform to the plans adopted at that date by the General Government, which contemplated the construction of longitudinal dikes to contract channels, and the use of dredgers to remove bars. These plans mentioned no specific depth of water to be secured.

The works of improvement begun by the Government in 1835 and completed in 1839, consisted of a revetment dike from Port Schuyler, 1 mile below Troy, to Breakers Island; the revetment of the island shore, and likewise the revetment of Hillhouse and Hanks Island; a revetment dike in front of Upper Patroon Island, and dams connecting it with the island and the island with the west shore; and a dike below Albany from Bogart Island to Beacon Island, and thence to Van Wies Point. The shores of these islands, and of Papscannee Island, directly opposite, were revetted, and dams were constructed between Beacon Island and the west shore, between Bogart and Westerloo islands, and between Westerloo Island and the west shore.

Revetments designed to protect banks against erosion were, in general, built of a single row of piles driven in juxtaposition, with a penetration of 10 feet, along the water's edge, firmly united and braced, behind which was laid compacted earth and gravel, paved with stone. When the object was to close secondary channels, piles in double rows, from 12 feet to 15 feet apart, were similarly driven and braced, and the intervening space filled with broken stone, gravel, and sand. The crests in both cases were placed about 2 feet above tidal high water.

After 1839 a long interval of time ensued during which nothing was done by the United States except what was absolutely necessary to maintain existing works, but in 1863 the State of New York resumed operations, and between that date and 1867 built six important dikes on the east bank from Greenbush to Houghtailing Island.

But these limited works failed to create any marked change in navigable facilities and the demand became universal for increased depths above New Baltimore to meet the wants of commerce, which had now assumed large proportions.



Congress made additional appropriations in 1864, and a project was formed in 1867 for a systematic improvement of the river, which contemplated 11 feet depth at mean low water from New Baltimore to Albany and 9 feet to Troy.

The plans embodied the following provisions:

First. A system of longitudinal dikes to confine the current sufficiently to allow the ebb and flow of the tidal current to keep the channel clear; these dikes to be gradually brought nearer together from New Baltimore towards Troy, so as to assist the entrance of the flood current and increase its height, their height to be kept approximately at the level of the tidal high water, so as not to confine the freshets; the exact level, however, being left to be determined by experience as the work progressed.

Second. That the dredge be used so far as necessary to open channels above described, which the current should not be allowed to do, except very gradually, lest accumulations dangerous to navigation be formed below.

Third. Keeping, as far as practicable, the side reservoirs open to the passage of tidal currents, by gaps at their lower extremities, in order to increase the tidal flow.

Fourth. Dumping all dredged material in secure places, where it could not be moved back again into the channel by the current.

Fifth. Constructing the dikes of timber and stone, in a manner to secure their permanency, at a minimum cost; the details, varying with the locality, to be left to the discretion of the local engineer, and to be so designed as to admit of giving at will an increased height to the dikes.

Sixth. To protect by revetments, when necessary, the banks and islands against the abrading action of the current.

Seventh. That limits be prescribed beyond which no encroachments upon the channel should be made.

The channel widths between the dikes built under this plan to revet the banks as well as to contract the waterway, vary from the minimum of 575 feet at Troy to the maximum of 1,200 feet at New Baltimore. The width at Albany is 850 feet, and the average width between Albany and Coeymans is 800 feet.

The average low-water discharge at Albany is about 3,000 cubic feet per second.

The dikes designed to confine the main waterway were of a construction similar to that adopted for closing secondary channels.

The cost of construction varied with the depth of water and the width of dike, but did not usually exceed \$15 per running foot of dike.

The project was practically completed in 1892, at an approximate total cost of \$1,500,000, the original estimate of \$1,000,000 being insufficient for the reason that inadequate appropriations prolonged the completion to twenty-five years, causing a great part of the work already built to be duplicated or extensively repaired. All work, both of construction and dredging, was executed, as a rule, by contract.

Since 1867 nearly all of the dikes have been built by the United States, and the dredging done by the State.

A new project was formed by the Government in October, 1891, providing for maintaining old improvements, and constructing new regulating works along 8 additional miles of the river below New Baltimore, as well as deepening the entire reach of the river under improvement, so as to afford a channel 400 feet wide and 12 feet deep, at mean low water, from Cocksackie to Troy, N. Y.

The estimated cost of the new project is \$2,500,000, provided the entire work be completed within five years.

The execution of the project is now in progress.

A model of the river, extending from Waterford, at the head of slack-water navigation, to New Baltimore, 14 miles below Albany, is on exhibition, affording an interesting study of the physical features of the river.



19. James River Improvement. Mattress dike and wing dam. Contributed by Col. W. P. Craighill.

These are used to contract the width of the river where it is needed, to produce and maintain a deeper channel in the shoaler reaches by first increasing the current, and thereby removing sand and other material deposited by the river until the original areas are restored or so far as to give uniform velocity.

A row of round piles, which are not less than 8 inches diameter under the bark at the small end, is driven 8 feet from center to center, as far as is necessary into the river bed. To these are bolted white oak wales, 6 by 8 inches, one at mean high-tide, the other at mean low-tide mark; the bolts are not less than 1 inch diameter, going through wale and pile with screw and nut on the back. In front of these wales sheet piling 3 inches thick is driven into the river bed as far as is necessary or possible without splitting the heads of the piling. A second row of piles is driven 10 feet behind the first, one-half in number of the first row, and the two rows are tied together with white oak struts, 6 by 8 inches, bolted to the front and rear piles with  $\frac{3}{4}$ -inch bolts and nuts. The struts incline downstream from high-water to low-water mark.

The outer end of the wing dam is further secured by a cluster of three white oak piles, not less than 8 inches under the bark at the small end, and not less than 35 feet long. These are bolted together with  $1\frac{1}{2}$ -inch bolts, and their tops are bound together with  $\frac{3}{4}$ -inch chain, and the wales of the dam are also bolted to them. These end piles are left at the height they were driven, except that their tops are cut off square and each one covered with sheet zinc fastened with copper tacks.

The front row of piles and the sheet piling is capped with pine 3 inches thick, spiked to both round and sheet piling. The latter is spiked to both wales also.

Layers of brush 3 feet thick, bound together with galvanized No. 12 iron wire, are placed on the bottom, covering it for 10 feet above the sheet piling, and when necessary extending 15 feet beyond the end of the wing dam, and this brush is first loaded with stone or gravel, two tons to the linear foot of wing dam, and afterward further covered with any suitable material from dredging and blasting, until the wing dam is covered to the level of ordinary high tide.

The timber used, except as above stated, is sound merchantable pine. The dams are soon more or less covered with deposit, and become masses of earth and stone, the timber work remaining as a core. Some of these dams were built 17 years since.

The mean rise and fall of the tide in the James at Richmond, Va., is 3.6 feet. The river is subject to considerable freshets, which average 10 feet above high tide, but occasionally rise to 20 feet, and one in 1877 rose to 25 feet.

The cluster of white oak piles at the outer end of the wing dams is left as high above water as the length of the piles allows to mark the position of the wing dams in freshets and in foggy weather.

These wing dams have done good service, increasing and maintaining the depth of the channel, and by diminishing the force of currents in freshets; in protecting the river banks and the training walls which are subsequently built to connect their outer ends. They are usually built at intervals of from 400 to 500 feet apart. The cost of these wing dams by contract is \$3 per linear foot in water from 0 to 20 feet depth at low tide, which includes all cost except the loading, which is added from excavation.

In the model the sanded boards are intended to represent the river bed.

The training walls on this improvement are used to connect the ends of the wing dams, when the latter are found to be of the proper length, and are intended when settled and finally loaded to be not higher than mean tide level.



The training wall consists of two rows of piles 6 feet apart, the piles in each row, driven 8 feet between centers, filled with brush, and the piles afterwards fastened to each other with wire.

The piles are round, at least 8 inches in diameter inside the bark at the small end, and 35 feet long, and are driven until a 2,000-pound hammer, falling 10 feet, sinks the pile only 5 inches with the last 5 blows, or its equivalent in mechanical force.

They are usually cut off 2 feet above high tide, but in deep water have been left at 8 feet above.

In between these piles, at right angles to the current, is placed a layer of brush 30 feet wide and 3 feet thick, which projects 15 feet in front of the piles and 9 feet in their rear. Any live timber is used for brush, but this bottom layer is made from small trees of sufficient length, fastened together in sections with wire. This layer is loaded at first with not less than 2 tons of stone or gravel to the running foot of wall. On this bottom layer a tier of brush is built up between the two rows of piles to their top parallel to the current. When the brush is in place and properly packed, the piles are tied together transversely and longitudinally with No. 12 galvanized iron wire, each set having twelve strands of wire, *i. e.*, six on each side.

This brush becomes loaded with silt and settles with the weight; additional brush is then put on from time to time until the wall is well compacted and of the proper height. It is loaded, especially on the outer face, with stone and gravel from excavation. If there is suitable depth of water inside a gap is left through which dredged sand and mud is carried and deposited in the rear. The gap is then closed. Deposits from the river gradually fill up these rear spaces, broken into lengths of 400 to 500 feet by the wing dams. Ultimately these walls will be of stone, dumped on them, the pile of brush forming the core, and covered with water at mean low tide. These training walls in water averaging 10 feet depth are built by contract for \$2 per linear foot. The older of them have been in use six years, and have answered their intended purpose perfectly, with no cost for repairs other than the occasional addition of brush for the first two or three years.

In the model the sanded boards are intended to represent the river bed.

## 20. James River Improvement. Drill platform. Contributed by Col. W. P. Craighill.

This model represents one of the smaller platforms used for the past twenty years on the James River improvement in submarine blasting. It consists of a water-tight compartment about 20 feet square and  $3\frac{1}{4}$  feet deep. This, when in place for work, is supported by four spuds, 12 inches square, resting on the river bed. The compartment is raised on these by wheel and screw gearing which acts on a rack on one side of each spud. For this size of platform the compartment is ordinarily raised by four men. When the platform is to be moved the compartment is lowered and the spuds raised sufficiently from the bottom; the platform can then be towed to any desired point. The small derrick is used for handling the steam drills, two of which can be used at once, and the timber supports to which they are fastened, which can be set vertical or at any desired angle practicable for the depth of water.

On this improvement the bottom of the excavation in rock is at least 29 feet below the floor of the platform as usually set in place. The steam power needed for the drills is supplied from a scow which also carries lifting apparatus for raising the larger fragments of blasted rock. Smaller fragments are dredged. The platform is moved away from the charged holes before they are fired. The average depth of holes drilled in 1891-'92 was about 7 feet, and they were spaced about that distance apart. About 1,000 linear feet of holes are drilled in a month, including all delays from moving, etc.



The splay in the spuds is given to reduce vibration so far as is practicable. The spud boxes are made larger than the spuds to meet this splay in raising and lowering the compartment.

As the platform is usually moved at high tide, the height to which the compartment is raised need not exceed 3 to 4 feet.

The improvement of James River was regularly undertaken by the United States in 1870. A small sum had been previously expended and was of some advantage to navigation. The total expended by the United States to July 1, 1892, has been \$1,302,408.19. In addition the city of Richmond has expended nearly \$500,000, but in the last five years only about \$50,000, and this near the wharves of the city.

When the improvement was undertaken by the Government navigation was obstructed by sunken vessels, by remains of military bridges, and by obstructions put in the river during the late war to prevent the national fleets from approaching too close to Richmond. There were also natural obstructions.

Rockett Reef and Richmond Bar had only 7 feet of water at mean low tide. From Warwick Bar (where the depth was 13 feet) to Richmond the channel was crooked and obstructed by dangerous rocks and ledges. The Dutch Gap Cut-off, which now saves  $5\frac{1}{2}$  miles of difficult navigation, was not then open.

The original project was to secure a depth of 18 feet at full tide, corresponding to 14.5 feet at low tide, to Richmond, with a channel width of 180 from Harrison Bar to Richmond docks, the excavation in rock to be  $18\frac{1}{2}$  feet at full tide. This plan was well advanced when Congress, by act approved July 2, 1884, adopted the project of 22 feet at mean low tide from Richmond to the sea. Operations during the past year have been conducted in accordance therewith. In carrying it out further a large amount of excavation will be in solid rock and the cost will necessarily be great. The width to be given to the channel is 400 feet from the sea to City Point, 300 feet from City Point to Drewry Bluff, and 200 feet from thence to Richmond. The methods employed for improving the river consist in dredging, rock excavation and the contraction of the waterway by means of dikes or jetties.

#### DUTCH GAP CUT-OFF.

The cut-off at Dutch Gap was made through a narrow neck of land about 450 feet across, connecting Farrars Island with the mainland and thus saving over 5 miles, the distance around Farrars Island, through a stretch of the river termed Trents Reach, and avoiding one of the worst shoals.

The cut was first made under the orders of Gen. B. F. Butler of the U. S. Army, during the civil war, in 1863-1864, with the intention of flanking hostile batteries at the point of the bend. It was carried through, but as a depth of only a few feet of water was obtained, it was not of much use. At the termination of the war the owner of land, Mr. Henry Cox, threw a causeway across the cut, stopping it up entirely. In the fall of 1870 a heavy freshet in the river swept through the cut, carried the causeway and other obstructions away, and gave an available depth of water of about 8 feet at low tide.

In 1871 the city of Richmond purchased the necessary land and deeded it to the United States. The cut was dredged out in 1871-1872 with the appropriation by Congress for the improvement of James River, making a channel available for navigation by obtaining a depth of water of about 12 feet at low tide. Since then, as appropriations have been made in the river and harbor bills, additional width and depth have been obtained.

The distance across Dutch Gap was about 450 feet; the width of the navigable pass is now, at its narrowest point, about 200 feet, with a depth of 18 feet at low tide. The rise of tide is 3.3 feet at this point. It is estimated that about 575,000 cubic yards of earth, sand, gravel, and indurated clay have been removed by blasting and dredging in making this improvement.



This locality, as are many other places on James River, is historic ground.

It was on Farrars Island, on the elevated plateau near Dutch Gap, that Sir Thomas Dale, in September, 1611, founded the "City of Henricus," named after Prince Henry, eldest son of King James I of England. Jamestown, where the first settlement was made by the English on this continent, is only about 42 miles below the "City of Henricus."

Sir Thomas Dale, who was in command of the colony at Jamestown, being relieved, determined to ascend the river, and chose this point for his new settlement. The location was easily defended, being on a plateau some 60 feet above the water on either side, with steep bluffs. A short stockade above and below across the narrow neck made a strong protection in those days on the land side against Indians, the only foes to be expected. He laid off the "City of Henricus" with three streets, erected a college for educating the Indians, to which he gave the name "University of Henrico," also a church, watchhouses, and many other buildings, the largest and most imposing being a house for himself.

There are still to be found some remains of this "City of Henricus," or Henricopolis, such as bricks, warlike weapons, etc., though it has been about 250 years since the settlement was abandoned.

It was but a few miles from Dutch Gap, at Varina, where Rolfe, with his wife Pocahontas, daughter of King Powhatan, first lived after their marriage, and it was here their only child was born.

#### LEGEND.

Old navigators on the river tell the following story to explain how this place received the name "Dutch Gap." In early colonial days a Dutch ship was anchored at Picketts, about 23 miles below Richmond. An Indian and a Dutch sailor, boasting of their skill in the use of paddles and oars, made a wager as to which could win a race from Picketts to Richmond; the Indian with his canoe and paddles, the Dutchman with boat and oars. When the Dutchman got to the gap the Indian was disappearing around the bend, a mile ahead. The Dutchman ran his boat inshore, after hard work got it across the gap, launched it, and started for Richmond, getting thus 2 or 3 miles advantage of the Indian. The Indian, believing the Dutchman was far behind and that he would easily win the race, took it leisurely and was utterly amazed when he approached Richmond and found the Dutchman already there and waiting with some friends at the landing to receive him with jeers.

#### 21. St. Johns River, Florida, Jetty. Contributed by Maj. J. C. Mallery.

The bar at the mouth of the St. Johns River is composed of sand. Before work began the mean low-water depth of the channel across the bar varied from 5 to 7 feet. The tidal range is 5.8 feet. The channel shifted north and south through a mile range.

The approved project is to form a channel across the bar 15 feet deep at mean low water, by the concentration and direction of the tidal currents by two jetties, to start from opposite shores of the entrance and to converge until, on the bar, their outer ends should be approximately parallel and 1,600 feet apart.

About three-fourths of the projected work has been completed at a cost of \$960,000. A permanent increase of  $4\frac{1}{2}$  feet in depth is still required under the existing project.

Under the influence of the jetties the channel has remained much more permanent in position and has at times attained a depth of 13 feet on the bar. This bar was previously noted for its dangers to navigation, vessels being wrecked on it at frequent intervals. Although commerce has greatly increased, no wreck has occurred since 1885, the jetty channel having been used exclusively since that date.

Nearly 5,000,000 cubic yards of sand have been removed by the action of the jetties.



## NORTH JETTY.

The total length of the north jetty is 10,991 feet. The work on this jetty was commenced in January, 1882. For a distance of 8,799 feet the foundation is composed of log and pole grillage mattresses, and from there to the end 1,856 feet of fascine mattresses, as shown in the model. The fascines are made of hard-wood, brush. The superstructure is composed of riprap, capped with concrete. Up to the present time 829 feet have been built to the full height and capped. The rest of the jetty has been built up to an average height of 5 feet below mean low water.

## SOUTH JETTY.

The total length of this jetty is 9,769 feet. Work was commenced in December, 1880; since which date the foundation has been laid for a distance of 6,668 feet with log and pole grillage mattresses, and thence to the seaward end of the jetty, a distance of 2,621 feet, with fascine mattresses, as in the model. The superstructure is of riprap, capped with concrete. Up to the present time, 1,740 feet of this has been built to the full height and capped. On the seaward end, for a length of 2,428 feet, the depth of water on the jetty varies from 6 to 18½ feet at mean low water.

22 and 23. Great Kanawha River Improvement. Part of Navigation Pass, Lock and Dam No. 6. Part of Navigation Pass, Lock and Dam No. 7 (full size). Contributed by Col. W. P. Craighill.

The following description of the movable dams on this improvement is taken from a paper submitted to Col. Craighill by Mr. Addison M. Scott, assistant engineer and published in Annual Report of the Chief of Engineers for 1892, page 2057.

"The movable dams are of the Chanoine wicket type, operated from trestle-service bridges. In general features they are all like Dam No. 7," illustrated by a model in this exhibit. "Dams Nos. 4 and 5 were completed and put in operation in 1880, and were the first movable dams in connection with slack-water improvement built in America. Dam 6 was completed in 1886. Nos. 7 and 8 are now building; both are well along, and will probably be completed during the present season, 1892.

"The operation of these dams on the Great Kanawha, the number of and time taken in the maneuvers, difficulties met with, number of days the dams are kept up, the cost of operating and maintaining, etc., each year, are fully described in the Annual Reports of the Chief of Engineers.

"The experience with movable dams on this river has on the whole been very satisfactory. They are easily and rapidly maneuvered (in these respects Dam No. 6 and those now under construction have considerable advantage over those first built), the expense of operation and maintenance is but little if any more than with fixed dams, and they prove highly satisfactory to the river interests.

"*Advantages over fixed dams.*—The movable dams are kept up whenever there is not water enough in the river for coal-boat navigation and down at other times. Their advantages over the ordinary fixed dam for a commerce and river like the Great Kanawha are decided, furnishing the benefits of the usual slack water without its most serious drawbacks. With fixed dams everything must pass through the locks; with them navigation is entirely suspended, too, when the river is near or above the top of the lock walls. With movable dams the locks are only used when the discharge of the river is so small as to make them necessary. At all other times they are down, practically on the river bottom, affording unobstructed open navigation. This is of great advantage to all classes of commerce, and is particularly so with coal, transported as it is, and empty barges returned. In 'fleets' of large



barges, more barges can of course be taken by a towboat, and much better time made by all kinds of craft in 'open river,' when there is water enough for such navigation, than when the stage or discharge compels the use of the locks.

"The movable dams being down in high water, there is comparatively little difficulty in protecting the banks about the works from the scour. In this respect they have considerable advantage too over the fixed dams.

"*Modifications, cost of operating, etc.*—Experience with the dams has naturally suggested improvements, and No. 6, the last one completed, has considerable advantages over those first built in strength and durability of construction, facilities for rapid maneuvering, and cost of operation and maintenance. Dams 7 and 8 have been still further improved in some of their details.

"No. 6 has been in operation over five years. The average cost of operating and maintaining the lock and dam has been \$2,515 per year. This covers wages, supplies, repairs, including considerable addition to the riprapping, and all expenses connected with the work. The entire cost during the five years of repairs on the dam proper and on all of its apparatus, including paints, one of the principal items, has been something less than \$250, or an average of \$50 per year.

"This dam is put up by four or five men in from seven to twelve hours; the usual time is about eight hours. It is lowered with the same force in about two hours. No material difficulty has ever been met with in any of the maneuvers at No. 6.

"Four men are employed regularly at each work, the same as at the fixed dams. In raising and lowering the dams one or two extra men are often hired.

"*Maneuvering the dams.*—The operation of raising and lowering the dams is generally understood, or will be inferred from [the models and views], but may be briefly described as follows: In raising the pass the bridge is first put up trestle by trestle (they are connected by chains, as shown), beginning at the lock. As the trestles come up, and with them the aprons that make the walk, the rails forming the connections and winch track are placed. In raising the trestles the winch (Plate 10) is used by means of the small top crane and sheave. After the bridge is up the wickets are pulled up one by one with the winch and wicket chains until the props drop into the hurter seats. The wickets are not erected or 'righted' as fast as pulled up, but left 'on the swing' (en bascule); that is, with the horse erect, the end of the prop in the hurter seat, and the wicket in a horizontal position at the top of the horse. In this position the water passes freely under the wicket. If righted as fast as pulled up, the head of water becomes so great that the last wickets can not be safely handled with the winch. After being put on the swing clear across they are all rapidly righted; this is done with the drum and brake on the winch and wicket chain, the butt of the wicket being held against the pressure of the water and let against the sill without shock. In lowering the pass the wickets are pulled up stream a few inches with the winch by a simple line and grab connection at the top of the wicket. This carries the foot of the prop out of the seat into the descending channel of the hurter, when the grab is disengaged and the wicket falls. After the wickets are lowered the bridge is put down. The maneuvers briefly described above refer particularly to the navigation pass. The weir is maneuvered on the same general plan, but the weir wickets being smaller than those of the pass, they can be raised or lowered, put on the swing, or righted with full head whenever desired. The maneuver of the weir when the dam is up is governed by the stage or discharge of the river, it being kept wholly or partly raised as required to regulate the surface of the pool. A pass wicket, for reasons given above, is never lowered or swung unless the whole dam is to go down."

#### 24. Key West Harbor, Florida. Contributed by Maj. J. C. Mallery.

The Florida Keys consist of a chain of rock and sand islands extending southwesterly from Cape Florida for nearly 200 miles. They are connected by extensive



sand flats overlying a soft oölitic limestone from which the sand is almost entirely formed.

This chain is a serious barrier to all shipping from the Atlantic to the eastern and middle gulf ports, and the straits between it and the West India Islands form a dangerous passage for vessel going further west. The chain is crossed by four navigable channels, of which the most easterly is the northwest channel of Key West Harbor, immediately west of Key West. It is this easterly position, as well as the proximity of the good harbor at Key West, that gives this channel its importance. It is used by vessels that do not draw more than  $10\frac{1}{2}$  feet of water, the greatest available depth over the bar that obstructs its northern end. In rough weather the available depth is reduced to 8 feet, and vessels of greater draught are compelled to make the dangerous and difficult passage to the channels near the Dry Tortugas, 60 or 70 miles further west.

The average daily tonnage through the northwest entrance is estimated at 2,500 tons. The shallow water on the bar not only restricts the tonnage but has modified the construction of vessels using it, producing a prevailing form which is neither safe nor seaworthy. Two important lines of steamships use the northwest entrance habitually, but can not build ships to suit their continually increasing trade; a third, the Mallory line, between New York and Galveston, touching at Key West, would use it if there were sufficient water.

The necessity for the improvement of this entrance was first brought to the notice of Congress in 1868 and an examination of the bar ordered. Nothing further was done until 1881, when another examination was made and in 1882 \$25,000 appropriated for dredging; with this in 1883 a cut 60 feet wide and 15 feet deep at mean low water was made across the bar, but it soon filled up.

In 1886, 1887, and 1889 accurate surveys, current and tidal observations were made under the direction of Capt. W. M. Black and submitted to a Board of Engineers, who in November, 1889, presented a final report and project for the improvement.

The new surveys indicate that the existence of the bar is due to the conflict between two tidal currents, one flowing north and south through the northwest passage and the other nearly east and west along the northern side of the general reef, and that there is ample energy in the strongest overflow currents, if properly directed, to maintain a deeper channel over the bar. They also make known the important fact that a bed of rock underlies the whole sandy bar at no great depth below the surface and that there is, in prolongation of the existing northwest channel, a natural ravine across the reef, now filled with sand, but forming a possible rock channel 1,000 feet wide and 24 feet deep at mean low water, the tidal oscillations being about 3 feet.

The approved project has for its object the improvement of the present bar channel (extent of improvement not predicted) by the construction of a stone jetty along the submerged reef on the northeast side of the northwest passage near its northerly end at an estimated cost of \$500,000. Work upon this bar involves so many uncertainties that the Board did not favor any present attempt to obtain the full 24-foot depth, but felt convinced that the improvement which may be fairly expected from a northeastern jetty will justify its cost, and moreover will form part of any future project to obtain the greatest depth (24 feet) permitted by the underlying rock formation.

Work was started on the jetty June 16, 1891, and at close of the fiscal year ending June 30, 1892, about 28,000 cubic yards of stone had been placed. The jetty is about  $1\frac{1}{4}$  miles long, with an average width at base of 25 feet and at crest of 10 feet. It is constructed by dropping stone overboard from barges, forming first a layer of stone over the whole length and then building up gradually to near low water, greater height to be given if shown by future observations to be necessary. It has



been in some portions brought within 1 foot of low water, but the crest of all the higher portions has been lowered by the force of the waves. It is thought that the stone used is not heavy enough to withstand the waves if placed above 3 feet below mean low water, even with a very wide crest. Stones weighing 1,600 pounds were displaced near northwestern end of jetty.

About \$130,000 have so far been appropriated for this work. The effect of the partly finished jetty has been to deepen the main channel to  $12\frac{1}{2}$  feet and to scour out some shoals between the channel and the jetty. Whether this deepening is permanent or not remains to be seen.

## 25. St. Marys Falls Canal Locks. Contributed by Col. O. M. Poe.

St. Marys River connects the waters of Lake Superior with those of Lake Huron. Its open navigation is interrupted at the Sault de Ste. Marie, where at the mean stages of water above and below, the descent is about  $17\frac{1}{2}$  feet in about three-quarters of a mile, varying about 2 feet; depending upon corresponding variations in the respective stages.

To overcome the difference of level, a canal about 1 mile long was completed in 1855, the cost thereof being defrayed by a grant of 750,000 acres of public land. The canal was 12 feet deep, and provided at its lower end with a combined lock, each chamber of which was 350 feet long and 75 feet wide, with a lift of 9 feet and a mean depth of  $11\frac{1}{2}$  feet over the miter sills. It is known as the canal of 1855, and is not shown by the model. By the terms of the land grant this canal was the property of the State of Michigan, which operated it until June, 1881, when the whole work was transferred to the United States.

In 1870 the General Government began an enlargement of the canal and the construction of a new lock south of the old ones, the canal prism being sufficiently widened for this purpose. This work was completed in 1881, at a cost of \$2,150,000, and is known as the canal of 1881. The lock of 1881 has a length of 515 feet between gates, a width of 80 feet in the chamber, narrowing to 60 feet at the gates, a depth of 16 feet on the miter sills at the mean stages of water (which is also the present mean depth in the canal), and a single lift equal to the difference of level. This lock is operated entirely by hydraulic engines actuated by two turbine wheels, and is represented in the model.

A further enlargement of the canal is now in progress, at an estimated cost of about \$5,000,000. It involves a navigable depth of 21 feet in prism and lock. The new lock (known as the 800-foot lock), occupies the site of the locks of 1855. It is 800 feet between gates, 100 feet wide throughout, overcomes the difference of level by a single lift, and has a depth of 21 feet of water over the miter sills at a stage somewhat below the mean of the last twenty-two years. The construction is well advanced, and the lock is represented in the model, which correctly shows its position in relation to the lock of 1881. It is to be operated by hydraulic engines, actuated by turbines.

Large as is the present lock (of 1881), it was taxed to nearly its full capacity during the two hundred and thirty-three days of the season of 1892, when 12,580 vessels passed through it, having an aggregate registered tonnage of 10,647,203 net tons (of 2,000 pounds each), and carrying 11,214,333 net tons of freight.

The average length of season at this canal is about seven and one-half months. During the remaining four and one-half months navigation is prevented by ice.

The traffic through this canal exceeds that of any other canal in existence.

## 26. Mississippi River, Reservoirs at Headwaters of. Movable Hydraulic Weir (first design). Contributed by Maj. W. A. Jones.

This design of a movable dam is intended to be used for a high or low head, and any width of dam. By closing the inlet valve communicating from the pond to



the hydraulic chamber, pressure from the pond is shut off and the dam remains stationary. The pond then rises and water flows over the crest of the weir. By opening the outlet valve, allowing water to flow out to the pond below, pressure on the dam is relieved, and consequently it lowers. These valves are operated automatically by means of an attached cable, by either the upward movement of the dam or by winding at the capstan. Tension on the cable will always close the inlet valve first, and then, if continued, open the outlet. When slackened, the outlet will close first and then the inlet is allowed to open. By these means, if the cable is so adjusted, the dam can be stopped and balanced at any desired point.

The weir is also provided with direct contact with bottom or bed of river by means of chains which operate when raised to its full height; is built of any required material, semicircular shape, and with a drag leaf at the bottom of the hydraulic chamber, which gives it a downward tendency at the point of bearing contact, so as to more readily inclose said chamber, as well as assist in resisting the overturning tendency; is built in sections hinged together, so that it may flatten out into its transverse trench, of minimum depth below the bottom of the channel. If built water-tight, it is filled with water; in any event, it is always allowed to fill, which assists in its operation; has an air chamber if necessary, to give it its slight buoyancy, which starts it in its upward course, and when a head is gained is gradually given over to the pressure of the head.

This weir may be used as a lock gate. The lock gate differs in the fact (as there are two or more gates) that the lower gate must be made heavier than water, so as to sink freely in dead water, and is raised by the pressure of the water applied to its hydraulic chamber from the upper level until it reaches the surface or point where the pressure in the lock chamber is in excess of the lower level sufficient to continue its upward movement as the lock chamber fills. The upper gate being buoyant is lowered in dead water by connecting its hydraulic chamber with the low level, and allowing the water to flow out, it is forced to the bottom notwithstanding its buoyancy.

The lock chamber is filled or emptied through ordinary sluiceways or over the crest of the gate, the water being taken from and delivered at the bottom of the lock chamber through channel provided beneath said chamber in the ordinary way.

This gate produces no pressure on lock walls.

Logs may be sluiced as follows:

Lower crest of weir until sufficient water is on it to pass them, then let them go over the top. As this weir is not dependent on its side walls for support, it can be made any length, greatly facilitating the sluicing of logs. By passing logs more rapidly over these wide crests a great saving in water is effected.

*Raft lock.*—Operated same as boat lock. Size of lock chamber does not complicate in the matter of construction or operation.

*Control of floods.*—In time of flood the weirs are lowered flat on bottom, and the river is easily given the same free section it had without the dam.

*Manipulation.*—One man can manipulate a weir of any size. The valves are easily handled.

This weir is patented.

## 27. Mississippi River, Reservoirs at Headwaters of. Movable Hydraulic Weir (second design). Contributed by Maj. W. A. Jones.

The gate is a combination of the improved and old forms of the "bear trap," and is intended to hold a head of 12 feet of water in the reservoir, or a head on the reverse side of 7 feet (the reservoir being empty).

When the water in the reservoir is the higher the gate will be operated as an



improved bear trap; when the water outside is the higher, the gate will be operated as an ordinary bear trap gate.

The navigable pass will be 40 feet wide, and will be closed at one end by this gate.

The gate will be made slightly heavier than water so that it will always sink when there is no head on either side. It will require from 2 to 4 inches head to operate the gate, and until this head is collected the gate will be raised to the surface of the water and held there by means of two swinging cranes. The weight to be raised will not be great, as the specific gravity will only be slightly in excess of that of water.

The leaves are proportioned for the following conditions:

(1) When operated as an ordinary bear trap and starting from a horizontal position, the tendency of any head to raise the gate is one and one-quarter times the downward pressure.

(2) When operated as an improved bear trap, to rise to the maximum height possible under condition (1).

The gate will be maneuvered by a sluice, 5 square feet in section, built in the pier and on a level with the floor of the navigable pass, and having a connection with a recess under the gate. The water in the operating sluice will be controlled by a reciprocating valve that will admit water under the gate from the upper level, or keep it out at the will of the operator. The valve in the operating sluice can be readily handled by one man, who thus has the gate under control, so long as there is a minimum head of water of from 2 to 4 inches.

By properly adjusting the operating valve the gate can be held in any position, and any depth of water allowed to flow over the crest.

## 28. Mississippi River, Reservoirs at Headwaters of. Movable Reversible Hydraulic Weir. Contributed by Maj. W. A. Jones.

Designed to meet conditions at Sandy Lake Dam, Minnesota, where a reservoir dam is sometimes subjected to a reverse head, due to the Mississippi River rising higher than the level of the water in the reservoir. The weir, with a modified middle leaf, is completed and in successful operation. This is an adaptation of the modified bear-trap weir. The pressure from a small hydraulic head will raise it when water from the upper pool is introduced into the closed hydraulic chamber beneath it. The weir must rise or fall from the filling or emptying of this chamber. The inlet and outlet flumes are controlled by a compound balanced valve. For filling or emptying the chamber, this valve is reciprocating. For holding the crest of the weir at any desired level, water is let in or out of the hydraulic chamber till the desired level is reached by the weir crest when the valve is properly set, and holds it there.

When the river below the dam rises to the level of the reservoir above, there will be no head to operate the gate. To supply maneuvering power air is introduced from an air pump or from a reservoir of compressed air into collapsible bags beneath and attached to the leaves of the weir. At this stage, to reverse the weir, water is pumped into the hydraulic chamber beneath the weir under sufficient pressure to raise it to a neutral position with the middle leaf horizontal. When a head has accumulated on the river side, the valve is set to admit the water from that side, the pump pressure is released, and the weir reverses.

The auxiliary hoist enables this weir to be used as a lock gate. The head of the upper pool will always be sufficient to maneuver the lower gate, but the upper gate must be handled in dead water. Hence it must have the auxiliary hoist. Both gates must be heavier than water so as to sink freely to the bottom in dead water.



## TO MANEUVER A LOCK.

1. *Boat going up.*—Upper gate raised. Lower gate down. Boat enters lock chamber. Lower gate is raised by using flume from upper pool. While it is rising the upper gate is slowly lowered, thus filling lock chamber by time the lower gate is up. Boat passes out.

2. *Boat going down.*—Lock chamber will be full or empty. If empty, fill it by raising lower and lowering upper gates simultaneously. Boat enters. Raise upper gate by means of auxiliary hoist. Lower the lower gate. Boat passes out.

The lock chamber is filled and emptied through ordinary sluiceways and over the crests of the gates, these being under easy control by means of the valves.

This gate produces no pressure on lock walls.

## TO SLUICE LOGS.

Lower crest of weir until sufficient water is on the crest to pass the logs. Then let them go over the top.

A weir controlling the St. Croix River, at Nevers, Wis., has a crest 80 feet long on a head of 16 feet. It passes 3,000,000 feet of logs per hour. One to be constructed on the St. Louis River will have an opening of 128 feet. It will pass about 5,000,000 feet per hour. By passing logs so rapidly over these wide crests, a great saving in water is effected.

## CONTROL OF FLOODS.

In time of flood the weir is laid flat upon the bottom and the river is easily and quickly given nearly as much free section as it had without the dam.

## MANIPULATION.

One man can manipulate a weir of any size. The valves, being balanced, are easily handled.

The principal features of this weir are patented.

## 29. Mississippi River, Reservoirs at Headwaters of. Winnebigoishish Dam. Contributed by Maj. W. A. Jones.

This model shows one of a series of dams constructed for maintaining and controlling the reservoirs at the head of the Mississippi River. The reservoirs are designed for the purpose of collecting surplus water, principally from the precipitation of winter, spring, and early summer. The same to be systematically released during the low-water season in autumn for improving the navigable depth of water in the Mississippi River as far down as Lake Pepin.

Four reservoirs are completed and the fifth is approaching completion.

It has been demonstrated that during low-water stages the gauge readings at St. Paul are increased somewhat more than 1 foot by reservoir supplies.

## DESCRIPTION.

|                      | Watershed.           | Water surface.       | Storage.        |
|----------------------|----------------------|----------------------|-----------------|
|                      | <i>Square miles.</i> | <i>Square miles.</i> | <i>Gallons.</i> |
| Lake Winnebigoishish | 1,422                | 155                  | 344,000,000,000 |
| Leech Lake           | 1,225                | 210                  | 225,000,000,000 |
| Pokegama             | 630                  |                      | 35,000,000,000  |
| Pine River           | 602                  | 22                   | 56,000,000,000  |
| Sandy Lake           | 384                  | 12                   | 15,600,000,000  |

Whole watershed area 4,263 square miles.

Total storage capacity 675,600,000,000 gallons.



30. Plant and Works of Construction. Improvement of the Mississippi River between the Mouths of the Ohio and Missouri Rivers. Contributed by Maj. A. M. Miller.

In character this reach of the Mississippi River, lying between its two principal tributaries, is more nearly allied to the Missouri River than to its parent stream, which at its junction with the former, at the head of this district, is by far the smaller of the two branches.

Flowing over a bed of soft sand and confined on one side at least by a bank of silt, its own former deposit, and which caves and melts away under the attack of a current already highly charged with sediment, it is not strange that the recession of each high water reveals many changes in the channel due to erosion, and the formation of new bars and shoals which divide into several channels, no one adequate to the demands of navigation, the stream which at high water filled its banks a mile apart, but which at low water has shrunk out of all proportion to the width of its bed, and discharges only a twentieth part (about 40,000 cubic feet per second) of its high-water volume.

The bars, which are themselves slowly and constantly moving downstream in great sand waves, divide the river into a succession or chain of shoals and pools, and it is on the crossing of a shoal between two pools that during low water the obstruction to navigation occurs. Then vessels are limited in their carrying capacity to such draft (often not more than  $3\frac{1}{2}$  or 4 feet) as will enable them barely to float over the shoalest portion of the channel through which they ply, and eventually such an influence becomes an important factor in the construction of vessels, limiting their maximum draft to about the mean depth on the bars during the season of navigation.

Although during high water (average high water rising about 23 feet above mean low water) vessels are not so confined to one channel, nevertheless a difference in stage of river does not indicate a like difference in navigable depths, as with a rising river the bottom may also rise and again scour out when the water falls. In well known instances there has been found less depth on bars at higher stages than were had when the river was lower.

The first efforts at improvement were naturally local and not embraced in a general plan applicable to the entire district, and were made at those points where the obstructions were most detrimental to commerce, namely, in the harbors of the larger cities and towns having valuable river interests. For many years the works undertaken were carried on under special appropriations for particular localities, and even now such detached works are called for by their several interests. It was not until 1872 that a general appropriation was made for the improvement of the district in accordance with an approved plan of work which estimated the total cost for the 200 miles embraced at \$3,000,000. In details the works undertaken followed the precedents that had been established by local works whether prosecuted by private or public means.

They consisted in the main of stone revetments of caving banks founded on longitudinal foot-walls of stone, or stone and brush, and of stone dikes, singly or in series, of various proportions, but of solid character and similar to the dams which were used to close the island chutes. The dikes were intended to narrow the waterway at low stages and thus deepen the channel beyond their ends. Such works being of great weight and resting on the soft, yielding river bottom, settled continually, and as often as they were raised to grade, under the added load they sank again and again, so that it was despaired of ever maintaining them. This system was finally rejected, and in 1879-1881 there was gradually developed and adopted the system at present in use, which is not only more rational in theory but



has proved successful in practice. For some time it was largely experimental, and many forms of construction and details were tried and modified and rejected, or improved and accepted. As finally evolved the scheme for improvement and the system of construction adopted to give a permanent low-water channel with navigable depth of 8 feet between St. Louis, Mo., and Cairo, Ill., are as follows:

(1) Not to attempt to shorten or divert the river from any channel it may have chosen, but to fix it in its main low-water channel in long, easy curves, and to prevent its changing.

(2) To close all side channels and island chutes, thus concentrating the entire low-water discharge through one channel, which was to be contracted to a uniform width of 2,500 feet, and to induce by scour an increased depth and more uniform slope and cross section.

(3) To protect from possibility of erosion the soft banks of the river, whether old or of recent deposit, particularly where unwooded, and to stop caving, which tends to deepen the bends and to lengthen the axis of the river and thus to reduce its slope and velocity, causing deposits in bars and shoals.

To close the island chutes and to contract the channel to the required width a system of permeable dikes or hurdles was devised, which, offering only partial obstruction to the passage of the water, are to check and reduce the velocity of the current, by virtue of which alone it is enabled to carry sediment, and thus during the higher stages of the river induce deposits in the great settling basins formed below the hurdles and not in the channel.

These hurdles consist of light foundations of brush and superstructures of piling and brush screens extending from the shore to the channel limit and placed singly or in series in which they are usually placed 1,000 to 2,000 feet apart. The foundation mattress is a basket work of brush (willow or cottonwood, cut 20 feet to 40 feet in length and 2 inches to 5 inches in diameter) woven on poles continuously for the full length of the hurdles, which are from 1,000 feet to 3,500 feet long. The mattresses are 65 feet to 100 feet in width, and are woven on small flats fitted with ways from which each section or flat-length is launched as it is completed. They are held in position for sinking by yokes passing around the brace piles or clumps of piles previously driven for that purpose on the line proposed for the upstream edge of the mattress. When a sufficient length is woven—the amount varying with the depth of water encountered—the mattress is ballasted with stone and sunk to the bottom, being guided into place by the yoke; weaving, however, is not interrupted, and the mattress is sunk as close to the flats as the depth of water will permit without tending to draw the mattress off the ways. The poles on which the mattress is woven are made continuous by splicing them together, securing the joint with wire and spikes, and the loose ends of the woven brush are fastened to the poles with nails to prevent tearing.

These mattresses are very flexible, fitting closely into the irregularities of the bottom and preventing scour across the line of the hurdle. For their construction 1 cord of brush is required for 125 to 175 square feet of mattress, and to sink them 1 cubic yard of stone is required for every  $1\frac{1}{2}$  cords of brush.

The guide piles are driven slightly in advance of the mattress in clumps of three, two piles in front with a brace pile behind, 10 feet to 12 feet apart, so as to afford a sufficient anchorage for the mattress during construction and sinking and to protect from drift all those parts of the hurdle lying below their lines. The tops of the clumps come within  $2\frac{1}{2}$  feet of the level of mean high water to prevent drift being carried over the hurdle at that stage. A heavy pile stringer bolted to them about 5 feet below their tops connects them in the direction of the length of the hurdle. After the mattress is sunk these clumps, being driven so close to its upstream edge, are protected by it from scour.



About 25 feet below the drift line a second row of piles, spaced 6 feet apart, are driven through the sunken mattress and each alternate pile is strengthened by a brace pile driven about 8 feet back of it and bolted to it at the top, at the level of the stringer on the drift row, and all piles in this row are connected by a similar stringer at the same level. In addition, the two rows of piles are connected by cross-braces bolted to the two stringers and spaced usually at every joint in the latter. The piles used are oak, sycamore, cottonwood. These soft woods are accepted, as they have been found to last long enough to secure the required deposits, when their usefulness is ended. All piles are driven large end down, without sharpening, by the aid of a water-jet, in addition to the ordinary pile-driving hammer.

To complete the hurdles the lower row of piles is wattled with brush or in deep water brush curtains are made between the rows of piling and below the cross braces, and one edge being held in position the other is weighted and swept down by the current to the bottom against the piles, forming a screen to check the flow of water, through which screen it filters. In order not to bring too great pressures on the hurdles immediately after construction and before a fill has been secured behind them, wattling is not often carried higher than within 10 feet of the top stringers or about 6 feet above mean low water.

On the upper line of a system of hurdles drift usually collects so quickly and in such quantity that curtains or wattling are unnecessary, and whenever a sufficient quantity of drift has accumulated above a hurdle a mattress is built over it and it is sunk with stone, affording an admirable protection to the hurdle from scour, other drift, and from ice.

The great danger to these dikes comes from the ice, which, in passing out in the spring, breaks them down or destroys them before their effect has been secured, necessitating expensive repairs or reconstruction. This is especially the case with those lines built during the low-water season in the fall of the year and which do not have an opportunity to secure a deposit before the breaking up of the ice.

To build in the spring, however, after the ice has passed out, is to build during high stages of river, in swift, heavy currents, with great tendency to scour, and troublesome obstruction by drift which often collects against the hurdles in great masses more than an acre in extent, and exerting tremendous pressures, with long leverages at the top of the piling to break and overturn it. The conditions greatly increase the first cost of construction.

At the junction of each hurdle with the bank the latter is revetted below the level of low water with a mattress about 200 feet in length and extending on both sides of the line of work, and above this mattress the bank is graded and faced with stone, to prevent erosion of the bank and scour around the end of the hurdle.

The cost of a completed hurdle has been from \$9 to \$16 per linear foot.

Wherever they have been tried enormous deposits have been gained, which when brought to the elevation of the mean stage of the river, about 10 feet above mean low water, quickly becomes covered with a growth of young willows and cottonwoods. This growth gains additional height for these bars by deposit from each succeeding high water, until the accretions become a new bank for the river forcing all water which once covered its territory into the proposed channel-way. This new bank in its turn must be protected from erosion.

At Horsetail Bar and Twin Hollows accurate determinations of these deposits or fill were made in 1888. The hurdles had been constructed in 1880-'83, and 29,000,000 of cubic yards of sedimentary deposit had been collected, averaging 14 feet deep over 1,275 acres of reclaimed river bed, at a cost of  $2\frac{1}{2}$  cents per cubic yard. The greatest depth of fill observed was 41 feet.

In the Pulltight, Jim Smiths, Sulphur Springs, Lucas, and Kennetts Castle reaches and in St. Louis Harbor proportionate results have been attained with marked in-



crease in the low-water depths of channels. Through Horsetail Bar—a stretch of about 5 miles and once a particularly shoal and persistent obstruction—steamers now pass freely at the lowest stages and rarely cast the sounding lead.

To protect the river banks from erosion woven brush mattresses are used, similar in construction to those used for hurdle foundations. They are made, however, in greater widths, rarely less than 120 feet, such as suffice to sheath the bank from low-water mark well out beyond the line of deepest water next the bank.

When the currents are very strong these mattresses are strengthened longitudinally by wire cables, which run their whole length and are in such number as is required to sustain the weight of the mattress while sinking; frequently, however, no cables are used, as the poles are sufficiently strong for all purposes.

These mattresses are sunk with stone in the same manner as the hurdle mattresses, in depths varying from 20 to 50 feet and in continuous lengths of 5,000 feet to 6,000 feet.

It is usual to place them during the low-water season, and after waiting for the next high water to partially grade the bank above their shore edges; the grading is afterwards completed and the bank is faced with stone to the top.

The banks of Arsenal, Chesley, Fosters, and Calico islands and the Illinois bank at Twin Hollows, McCauleys, Rush Tower, and Fort Chatres have all been effectually protected in this manner.

The cost of such a revetment has been about \$6 per linear foot for mattresses 120 feet in width and \$4 per linear foot for grading and facing the bank with stone.

The work has now progressed about 50 miles from St. Louis and the cost has been about \$85,000 per mile of river, but the estimates for the future must be increased at least 25 per cent on account of recent statutory restrictions upon the employment of labor on public works.

### 31. Mississippi River, Upper. Construction of Brush Dam. Contributed by Maj. A. Mackenzie.

Shows method of revetting banks and building rock and brush dams; with barges and "grasshopper" in position for sinking a mat; moorings, etc.

Model built at United States Des Moines Rapids Canal Shops, Keokuk, Iowa, under direction of M. Meigs, United States civil engineer.

Scale of model,  $\frac{1}{48}$ .

### 32. Mississippi River, section of, before improvement; and

### 33. Mississippi River, section of, after improvement. Contributed by Maj. A. Mackenzie.

Following is a description of the methods adopted in these improvements, with statements of the results attained.

## THE UPPER MISSISSIPPI RIVER FROM ST. PAUL TO THE MOUTH OF THE ILLINOIS RIVER.

This division of the Mississippi River is 690 miles in length, as measured along the low-water channel, and commencing with an approximate width at St. Paul of 900 feet, it gradually widens or increases in area of section as its tributaries join it, until at the mouth of the Illinois River it attains a width of about 4,500 feet.

The principal tributary streams are the St. Croix, Chippewa, Black, Wisconsin, Rock, Iowa, Des Moines, and Illinois rivers.

The high and low water discharges at St. Paul are approximately 60,000 and 3,000 cubic feet per second, respectively; at the mouth of the Illinois River, 370,000 and 50,000.



The bluffs which bound the valley in which the river flows are seldom 10 miles apart, generally 2 or 3 miles only, and often even closer together; and as the channel winds about, now among the numerous islands, now following closely the rocky shores and passing numerous towns and villages at intervals of a few miles, very beautiful and attractive scenery is often presented.

Railway and wagon bridges, 35 in number, span the river between Minneapolis and the mouth of the Missouri River; of these 19 are drawbridges, having channel openings of from 100 to 200 feet in width and raft spans of from 250 to 300 feet; 3 are pontoon drawbridges with openings of 320 to 380 feet, and 13 are high continuous bridges with a clearance of about 55 feet above high water and channel spans 240 to 428 feet in length.

The river (except at the Rock Island Rapids and Des Moines Rapids) has a gentle current, the fall between St. Paul and the Illinois River being 278 feet, an average of four-tenths foot per mile. The fall on Rock Island rapids is 20.4 feet in 15 miles, and on the Des Moines rapids, 22.2 feet in 11 miles.

In Lake Pepin, 21 miles long, through which the river flows, there is a scarcely perceptible current, the fall being about  $\frac{1}{2}$  inch to the mile.

In former years, when the whole traffic of the valley was carried by water, the passenger and freight business was very large, but at the present time the greater part of this business is done by the railroads paralleling the river on both sides; freight rates, however, being regulated during the season of navigation by the cost of water transportation.

The most important business carried on in connection with the navigation of the Upper Mississippi River is the raftings of logs and lumber, which gave employment in 1892 to about 100 towboats, while the mills along the river manufactured 1,420,530,929 feet of lumber and 563,397,275 shingles.

Taking into consideration the logs and lumber floated in the stream, the gross tonnage of the Upper Mississippi River for 1892 was approximately 4,500,000 tons.

In the natural condition of the river, before any improvements had been undertaken by the General Government, the many sand bars and crooked channels seriously hindered navigation at low-water stages, and at two localities—the Rock Island Rapids and the Des Moines Rapids—swift currents and obstructing reefs or chains of rock entirely blocked navigation or compelled tedious and expensive transfers by lighters or railroads.

At the Rock Island Rapids a canal 200 feet wide and 4 feet deep at low water has been excavated through the obstructing chains of rock; at the Des Moines Rapids the lower portion has been improved by a lateral canal affording 5 feet, the upper portion by rock excavation to the same grade. These works were practically completed in 1878, the former at a cost of about \$1,145,000; the latter, \$4,300,000.

As the improvements at the rapids approached completion, the difficulties attending the navigation of the sandy portions of the river became the more apparent, and while further improvements on a smaller scale have been carried on at the rapids, the main work during the past fourteen years has been in connection with the sandy river.

The Upper Mississippi is a shallow stream, of gentle current, with numerous islands and shifting sand bars. Little earthy matter is carried in suspension, the sand, forming the chief obstruction, being moved along the bottom by the action of the current, especially at high stages of water, when the current is much accelerated. In threading its way between the bars of moving sand, the channel is generally shoal, and at those points navigation is often difficult. The existence of islands dividing the waterway into two or more channels often results in shallow water and obstructed navigation. Caving of the banks occurs in the bends and at



other points, which, although not as extensive as is observed on the Lower Mississippi, still continually adds material to the bars which form obstructions to navigation.

The principal methods employed in the improvement of the Upper Mississippi comprise the protection of caving banks by revetting with rock and brush, the closing of side chutes, and contraction of waterway in the wide places by dams of rock, brush, and gravel. In addition to work of construction, bowlders are occasionally removed and channels dredged through bars containing hard material.

The work of removing snags, wrecks, etc.—a prime requisite in the improvement of river navigation—has been carried on during several months of each season since 1867 by the snag boats, thereby greatly lessening the dangers of navigation. The total amount expended for snag and dredge boat service to June 30, 1892, is \$624,640.

Desultory work had been done at special localities under small appropriations prior to the year 1878, but it was during that year that systematic improvement was begun. Since that time the work has been carried on continually under the appropriations available, and up to December 31, 1892, 66 miles of dams and 70 miles of shore protection had been constructed, consuming 2,511,473 cubic yards of rock and brush.

There has been expended on the general improvement of the Mississippi between Minneapolis and the mouth of the Illinois River, from the commencement of work to July 1, 1892, \$2,561,045.93. This amount includes expenditures for surveys, guages, and meter work, construction of plant, and other contingencies.

The condition of the canal of the Upper Mississippi prior to inauguration of works of improvement was such that at low stages the larger boats were unable to proceed further up river than La Crosse or Winona, or to points even lower down. In all such cases freight was necessarily reshipped on small and light-draft boats or barges for additional progress up the river. Such favorable results from the improvements already made have been attained that reshipment is no longer necessary, and boats of the largest size used on the river reach St. Paul with comparatively little difficulty.

During the low-water period of 1891, which was an extremely low-water year, the river reaching at many points a lower stage than in 1864, the low water of which was the lowest hitherto known, the Barnard, believed to be the heaviest draft boat on the river (with one exception), made a trip from St. Louis to St. Paul. On this trip many obstructing bars were met with and much trouble was experienced at unimproved portions of the river, but at points where works of improvement have been completed little or no difficulty was found. In 1864, prior to the inauguration of river improvement, navigation was almost wholly suspended, the very lightest boats being unable to reach St. Paul. In 1877 the situation was nearly as bad, although the low-water stage was in that year three-quarters of a foot higher than in 1864 and 1891. Such a trip as was made by the Barnard would have been an impossibility fifteen years ago to any but the lightest and smallest craft.

The improvement of the Upper Mississippi River is a work which can be best carried on so gradually as to give the river itself full opportunity to assist in the formation of proper channels, and, if carried to its fullest limits, the work must extend over many years. It has been the custom in carrying out work on the Upper Mississippi to select, when funds are available, such localities for improvement as may be at the time most detrimental to navigation. Each and every locality thus improved has a beneficial result on the navigation of the whole river, and as the shoalest bars have been improved from year to year, the ruling navigable depth has been considerably increased. By this method the good effects of work are spread over the entire stretch of river, and the improvement of the river, considered as a whole, is made progressive, the expenditure of each successive appro-



priation resulting in further and immediate benefit to the interests of continuous navigation.

34. Mississippi River, Upper. Dry Dock, Des Moines Rapids Canal.  
Contributed by Maj. A. Mackenzie.

Shows portions of dry dock at Des Moines Rapids Canal, with one gate and method of suspension, filling and emptying culverts, cradles, centrifugal pump, etc.

This dry dock adjoins the Des Moines Rapids Canal and is entered from it through gates with opening of 80 feet. The dock is 400 feet long and 100 feet wide. It was built by the United States Government in 1883-1889.

The main gates are built of iron, with oak arms and cypress planking.

Model built at United States Des Moines Rapids Canal Shops, Keokuk, Iowa, under direction of M. Meigs, United States civil engineer.

Scale of model : One twenty-fourth.

The following description of this improvement has been prepared by Maj. A. Mackenzie:

The Des Moines or Lower Rapids of the Mississippi River extend from Keokuk (3 miles above the mouth of the Des Moines River) to Montrose, a distance of about 11 miles, with a fall in this distance of 22 feet. In places the fall is as great as 7.77 feet to the mile. Formerly during low-water seasons these rapids interposed a serious and at times an absolutely impassable barrier to steamboat navigation.

A plan for improving the natural canal of the river by excavating a channel through the rock was recommended by Lieut. Lee, Corps of Engineers (Gen. R. E. Lee), in 1837, and a little work was done at that time. Work under this plan was resumed twenty years later, under the direction of J. G. Floyd, United States agent, and about 25,000 cubic yards of rock excavated. The channel was somewhat benefited by this work, but the results were not commensurate with the cost, and when the improvement of the rapids was again brought under consideration in 1866, it was determined to abandon the former plan and construct a lateral canal around the obstructions, and in 1868 work on the canal was commenced. In 1877 the work was so far completed as to permit the passage of boats, and the canal was opened to navigation.

Before improvement there was less than 1 foot of water at low water to be found at some points in the channel over the rapids; now there is a slack-water navigation affording 5 feet least depth around 8 miles of rapids, and a channel of same depth and 200 feet wide over the remaining 3 miles.

The Des Moines Rapids Canal extends from Keokuk to Nashville, a distance of about 8 miles. It is formed by an embankment in the bed of the river, giving a width of prism of from 250 to 300 feet. The embankment is built of earth, thoroughly protected by riprap and paving; is 10 feet wide on top, with slopes of  $1\frac{1}{2}$  feet base to 1 vertical, and its top is 2 feet above extreme high water. There are two lift locks, with lifts of 8 and 10 feet, respectively, and one guard lock. The locks are 350 feet long between the gates (available length about 325 feet) and 80 feet wide. Five feet of water is given on miter sills at extreme low water. The locks are filled and emptied through culverts with entrances in the gate recesses, and discharged through the side walls of canal. The culverts and main gates are operated by hydraulic pressure. Boats can be passed through the locks, under favorable conditions, in about ten minutes.

At the lower lock of the canal are located the offices and repair shops.

The total cost of the Des Moines Rapids Canal has been about \$4,500,000.

To provide for the repair of the large fleet of boats, barges, dredges, and other classes of plant used by the United States in connection with the improvement of the Upper Mississippi River, and for the repair under proper conditions of boats



belonging to private individuals, the construction of a dry dock at the Des Moines Rapids Canal was authorized by Congress in 1882, and construction was commenced in 1883 and completed in 1889, the total cost being \$133,000. The dock is located on the river side of the canal, just above the middle lock. It furnishes a basin 400 feet long and 100 feet wide. The entrance is from the canal through gates with openings of 80 feet. The inner or west side of dock is formed by the canal embankment; the outer or river embankment is of earth, with a puddle wall 4 feet wide and resting on the rock bottom. The embankment is protected outside and inside by a paving of rip rap face stone, averaging 15 inches in thickness. The abutments of the gates and sluices are of cut-stone masonry. The bottom is of gravel, resting on solid rock, and covered with paving stone. The grillage for carrying boats consists of eight longitudinal stringers, each 400 feet long, resting on concrete wall 30 inches deep and 24 inches wide; the timbers are bolted to the concrete wall at intervals of 6 feet; cross timbers, toggled together so as to be removable, rest on the longitudinal timbers at intervals of 16 feet, making a flat bed for boat to rest on 400 feet long and 50 feet wide. Drainage is provided for, according to the stage of water, by sluices through outer embankment, by a drain emptying through a cut-stone masonry culvert behind the eastern gate of dock. This culvert is 7 feet wide and 8 feet high, with arched roof. Connection with canal is through four openings, each 3 feet wide and 5 feet 10 inches high; the culvert discharges into a sump with its bottom 4 feet lower than lowest part of dock proper. The sump drains into the river through four openings similar to those of inlet culvert. The openings for filling and discharging are closed by cast-iron gates which slide vertically. These gates are raised by a hydraulic jack of 7 tons capacity, which is on a truck, and moved from gate to gate. Balanced valves are also provided for some of the outlets.

The head gates of the dock are of simple construction; the heel post, vertical posts, and diagonal rods of the gate, and the hollow quoin, are of iron; the arms are of oak; the sheathing is of 3-inch cypress, tongued and grooved, put on diagonally. This sheathing is placed on the lower or lock side of the gates, thus preventing any great lifting effect when the dock is empty, and adding to the life of the arms by keeping all but two upper arms constantly submerged, and these two upper arms can be readily replaced without interfering with the use of the dock. There is no miter post proper, the arms abutting against a 4-inch plank. By means of pivots 10 inches in diameter, at top of heel posts, collars, iron casting on the coping of abutment and anchoring rods, the gates are suspended without the aid of columns and no rollers are used. Notwithstanding the length of gates as compared with their height, their construction gives them sufficient stiffness to permit of swinging without appreciable settling of outer end when there is no water in the canal and dock.

The dock has been in constant use since completion and has served admirably the purpose for which it was constructed. The largest class of boats can be docked in a comparatively short space of time, with steam up, and without removing cargo, affording opportunities for frequent examinations and for minor repairs which would not be undertaken at any private boat-yards, where considerable time is consumed in hauling out and launching.

### 35. Mississippi River, Upper. Dams of Various Types. Contributed by Maj. A. Mackenzie.

Shows brush, rock, and pile dams of various constructions.

- (1) Brush and rock closing dam, 18 feet high.
- (2) Brush and rock wing dam, 10 feet high.
- (3) Brush, pile, rock, and gravel dam, 10 feet high.
- (4) Brush and pile temporary wing dam.



(5) Anchorage mat for mooring purposes.

Model built at U. S. Des Moines Rapids Canal Shops, Keokuk, Iowa, under directions of M. Meigs, United States civil engineer.

Scale of model: One twenty-fourth.

35a. New York Harbor Improvement. Model of Sandy Hook. Contributed by Col. G. L. Gillespie.

New York Harbor has two entrances: one, the southern or main entrance, leads through Gedney and Main Ship Canals and the Narrows into the Upper Bay, and is used by the southern coastwise and all transatlantic steamers and vessels; the other, called the eastern entrance, leads through Long Island Sound, East River, and Hell Gate, and is used chiefly by eastern coastwise vessels and steamers.

The Hell Gate entrance has been in course of improvement since 1869, and navigation through it will be much benefited on the successful completion of the existing project, now assured within a few years.

The southern or main entrance, to which this paper refers, furnishes superior facilities for navigation. The distance from the Narrows to the 30-foot curve of the ocean beyond the bar, measured along the Main Ship Channel, is 15 miles, approximately, and the range of tides is 4.8 feet.

Prior to 1884 the approximate depth on the bar was  $23\frac{1}{2}$  feet at mean low water, and on inlying shoals in the Main Ship Channel  $22\frac{1}{2}$  feet. The width of the channels did not exceed 600 feet.

These channel dimensions were adequate at that date for the commercial requirements of the port, but as transatlantic steamers gradually increased in length, tonnage, and draft, harbor improvements in the lower bay became necessary to prevent delays and detentions of vessels at the shoal obstructions, even at high tide.

The project for improvement which received the approval of the Secretary of War in 1886 provided for dredging a channel 1,000 feet wide and 30 feet deep at mean low water, from deep water beyond the bar through Gedney Channel and the Main Ship Channel to the Narrows leading into the Upper Harbor.

Although the channels selected for improvement were favorably located in regard to flow of the tides, no sure prediction could be given that they would be self-maintaining after improvement; hence provision was made for the contingent construction of a riprap contracting dike, springing from a suitable point on Coney Island and running thence southward over the shoals to a terminus, to be determined by experience, at the eastern end of Romer Shoal. Adequate stone revetments and spurs for the permanent protection of the northern shore of Sandy Hook against abrasion by the increased currents formed part of the plan.

The estimated cost of the projects by dredging alone was \$1,490,000, and by dredging and dike construction combined, \$5,000,000.

The work was successfully completed by dredging alone on October 10, 1891, at a total cost of \$1,440,000. From Gedney Channel 1,600,000 cubic yards of material were removed, and from Main Ship Channel 3,275,000 cubic yards; total, 4,875,000 cubic yards.

The highest price paid was 54 cents per cubic yard for the first 300,000 cubic yards, removed in 1885. Later, contracts were made at  $16\frac{7}{8}$  cents per cubic yard, but the average price paid for the entire improvement was about 25 cents per cubic yard.

No expenditures were made for the construction of any contracting dike closing minor channels through the shoals lying northward of the improved channel, and it is not expected that any such work will be undertaken at an early day, if ever.

The dredging was done by contract, and the contracting company in charge during almost the entire period of improvement, and to which great credit is due



for the successful results obtained, was the Joseph Edwards Dredging Company, of New York City, which owned and employed the steam dredgers, *Mt. Waldo*, *Advance*, and *Reliance*.

The dredging was done by the use of centrifugal pumps, with suction pipes 15 inches in diameter, arranged in pairs in vessels propelled by steam.

The material composing the bar in Gedney Channel consisted of large gravel and shingle overlying coarse sand; and that of the inner channel of finer grades of sand alone, except in the northern branch of the Main Ship Channel, where the bed was covered with a deposit of clay a few inches in thickness, derived from the Raritan River.

Two methods of working were followed. One, by which the vessel remained constantly at work on the shoals, depositing the pumped material into scows for transportation by tugs to the dumping ground at sea; and the other, by which the material was pumped into bins arranged in the hold of the vessel, and afterwards dumped at sea by the vessel itself. In the latter case the bin capacity of the vessel was 600 to 700 cubic yards, approximately. The former method was the more expeditious, but could be adopted on the inner channels only when the sea was quiet or comparatively quiet. No scows were ever used economically on the outer bar.

The coarse sand and gravel, singly or combined, were raised with great facility; and, once deposited, were nearly all preserved for measurement. The fine sand, on the contrary, was easily raised by the pumps, but, being light, was more freely held in suspension in the water, and therefore less of it proportionately was stored for ultimate measurement. An appreciable quantity passed overboard with the waste water, increasing in percentage as the retained material approached the top. When the sand was slightly covered with clay, additional embarrassments were experienced in keeping the pumps clear.

The dredged material was all dumped at sea in 16 fathoms of water, near the Scotland Light-ship, situated to the southward of the entrance to the south channel. The longest distance between the site of excavation and that for dumping was 12 statute miles.

The daily average aggregate yield of the two pumps of the dredger while at work on Gedney Channel was at the rate of 10 to 15 cubic yards of material per minute during 5 to 6 hours' pumping, and the average daily dumps, under favorable circumstances, were about 4,000 cubic yards.

Similar pumps, working in the inner channels without scows, where the material was lighter and the pumping rate much less per minute, and whence the haul to the dumping ground was greater, rarely yielded more than from 1,200 to 1,400 cubic yards per day.

When scows were used with the dredger, the average daily returns from the inner channels were about 4,000 cubic yards, the same as in Gedney Channel with the dredger alone, but the cost was nearly doubled, owing to the increased quantity of plant required.

The existing depth throughout the channels, resulting from the improvement, exceeds 30 feet at mean low water, which is greater by  $1\frac{1}{2}$  feet, approximately, than the original depths at mean high water.

Surveys have been made at periodic times during each year since the project was completed, but as yet no tendency toward deterioration has been noticed at any point of the channels.

The steamer *Reliance*, of which a transparency is on exhibition here, was the last dredger employed by the contractors on the improvement. It has since become the property of the United States by purchase, and will be kept in service hereafter to maintain unimpaired the improved depth of 30 feet at mean low stage.

A brief description of the machine, and its method of operation, may be of interest.



This dredger is provided with two pumping outfits independently arranged, so that either can be operated regardless of the other, each outfit having a centrifugal pump, engine, suction, and discharge pipes. The suction pipes corresponding to the size of the pumps, one on either side of the steamer, are located about amidships, and extend laterally from the pumps to the outside of the ship; then they turn with an easy bend at right angles, extend (when not in use) along the sides of the dredger, and are held up, lowered, and raised by suitable hoisting purchases worked by hoisting engines. These suction pipes, 15 inches in diameter, are about 60 feet long, terminating about opposite the stern of the ship, with suitable mouth pieces, termed drags, to fit on the bed of the channel and facilitate the ingress of the material.

To render the suction pipes flexible, so as to accommodate themselves to the pitching and rolling motions of the steamer, a section of them about 12 feet in length, located a few feet from the bend, consists of rubber: these flexible sections being supported by a special hanging arrangement of chains, blocks, and hoisting purchases against the vertical strain caused by the weight of the suction pipes themselves and what passes through them, and by tension chains against the longitudinal strain of the drags resting on the bottom. The steamer is provided with special arrangements to afford a long flow of the mixture of mud, clay, sand, and water, between the discharge from the pumps and the overflow outlets, to facilitate the settlement of the solid material in its bins.

The steamer is kept under headway from the time she leaves her anchorage in the morning until she returns to it at night. When she reaches the channel the suction pipes are lowered to an angle of from 30 to 40 degrees, to bring the drags in contact with the bottom. To keep the vessel on her line of work and supply the drags with material, she is kept constantly under steering headway. As soon as the sand bins are filled, the suction pipes are hoisted out of water, and the steamer put under full headway for the dumping ground. While she is turning to return to the work again, the dump gates are opened and her cargo discharged—the discharge being facilitated by pumping water into the bins with the dredging pumps. On again reaching the work her speed is slackened, drags lowered, and pumps started—and so on until the time to return to her anchorage for the night.

Maps of the Lower Bay, New York Harbor, are on exhibition showing the conditions of the channels before and after improvement.

A model is exhibited of the shore protection constructed at Sandy Hook, New Jersey.

Small sums of money have been spent at this locality at different times, beginning with the year 1864, for building isolated spurs to arrest sea erosion. Construction began only when some important interest was menaced, and was stopped when that interest seemed to have been protected. No funds were available for any complete or comprehensive project of improvement, and therefore the jetties which appear upon the model of the Hook do not represent parts of a systematic plan, but only distinct expedients employed to meet special emergencies occurring at wide intervals of time.

The Hook, during the thirty years of this desultory improvement, was constantly changing in length and configuration; at one time the eastern shore was invaded by the sea; at another, the northern point was thrust well forward into the deep-water channel, only to be pushed back again during succeeding years; and again the northern curve was flattened and the spit prolonged to the westward, inclining to the formation of a bight on the west side similar to the Horseshoe and Spmaceti coves, formed previously to the southward, on the same shore.

In 1884, when Government interests of large extent had become concentrated on the north shore, sea currents resulting from northerly and northeasterly storms



again actively threatened to break through the protecting bluffs there, and to undermine the foundations of public buildings.

Protection was sought in the construction of three concrete jetties on the northeast shore, anchored well into the bluff line and running outwards, to low-water line. The old jetties situated farther to the eastward, which had become ruins, were strengthened and built up to conform to the existing beaches.

On completion of this new work twelve spurs of different constructions and utility crowned the northern and eastern shores of the Hook.

For six years they were left alone to battle with the waves and currents without repair or extension, when action again became imperative in 1890 to protect the foundations of the shore beacons and other public buildings.

Newly prepared charts showed that the detached jetties previously built had served to extend and build up the foreshore during the period of suspended work, but that the high-water line had everywhere receded, at many points as much as several hundred feet. It was very evident that full and complete protection could not be secured by the use of jetties alone, and that the intervening beaches could only be preserved by a supplementary construction located near the high-water line.

The project of improvement adopted in 1890 provided for the repair of all existing jetties (including the southward prolongation of abutments), and for their connection at the shore ends by a continuous riprap wall located just below the high water line, with short spurs in rear extending close up to the dune line to prevent rear racing of the waves, the irregular alignment of the wall itself preventing front racing.

The crest of the wall when the stones were first laid was 5 feet above the general level of the adjacent beach, and the cross-sectional area was 50 square feet, approximately.

The slope of the adjacent foreshore was somewhat precipitous, and as the main object of the improvement was to preserve the high-water line and the dunes behind it—there being no marked tendency of the currents to cut below the low-water line—it was deemed best not to prolong the outer ends of the jetties beyond the latter line.

The stones composing the riprap wall, jetties, and spurs varied in weight from 300 pounds to 3 tons, and were laid directly upon the beach, with the purpose that each stone should arrange its bed quickly after the sea attack, allowing a gradual settlement of the wall without sudden dislodgment of the stone. The project was completed in 1892.

The length of wall is 2,500 feet, and the cost of construction, including repairs of settlements, was \$7.50 per linear foot.

As a result of the improvement the shore has not only been perfectly protected against abrasion by sea action, but the high-water line has moved outwards progressively.

The space behind the wall has filled in with sand, raising the contiguous beach several feet, and in places the wall has been covered to such an extent that its alignment can not be seen.

### 36. Ohio River Improvement. Davis Island Dam. Contributed by Maj. A. Stickney.

Five miles below Pittsburg, Pa., on the Ohio River. Designed and constructed under the direction of the late Lieut. Col. W. E. Merrill, Corps of Engineers, with Capt. F. A. Mahan, Corps of Engineers, in local charge.

The work consists of a lock 110 feet wide and 600 feet between gates, a movable dam of the Chanoine type, 1,223 feet long with a navigable pass 559 feet wide, and



a fixed dam across a secondary channel. The lock gates are closed by being pushed out horizontally by steam power on tracks at right angles to the axis of the lock; when open, they occupy recesses in the bank.

Work was begun on August 19, 1878, and the lock was formally opened to navigation October 7, 1885. The cost of construction was \$810,000.

The following description of this work has been furnished by Maj. Amos Stickney, Corps of Engineers, in charge.

#### GENERAL DESCRIPTION.

The Chanoine dam at Davis Island, which was formally opened October 7, 1885 is the first of a series of movable dams devised for the radical improvement of the Ohio River. It is located  $5\frac{1}{2}$  miles below Pittsburg, and is designed to make slack-water between the dam and Lock No. 1, on the Monongahela River, and on the Allegheny River to Thirty-sixth street,  $2\frac{1}{2}$  miles above its mouth.

The lock is located on the north side of the Ohio. The distance between the gates of the lock is 600 feet, and the total width of the lock is 110 feet. The noteworthy difference between this and ordinary locks is in the employment of rolling instead of swinging gates, and in the construction of recesses for the reception of the gates when open. These recesses or slips are built towards the shore, from the lock, a distance of 120 feet. The total length of the river lock wall is 689 feet. The wall is 11 feet thick, and has a height of 17 feet above and  $2\frac{1}{2}$  feet below the gate sills, making a total height of  $19\frac{1}{2}$  feet. The land wall (including the development of the recesses for the gates) is 1,169 feet long.

The movable dam begins at the river lock wall at a point 100 feet above the lower lock gate, and extends to the abutment on Davis Island. The dam is divided into four sections, viz: (1) The navigable pass, which is composed of 139 wickets, 4 feet  $\frac{1}{4}$  inches between centers, and 40 wickets 4 feet between centers, making a total width of pass of 719 feet. (2) The bear-trap chute, 52 feet wide, which is composed of two timber gates hinged to the foundation and operated by the water pressure being admitted and released from beneath the gates. The object of this chute was to relieve the Chanoine dam from the large quantities of driftwood which is prevalent in the Ohio River. (3) Weir No. 1, 212 feet wide, which has 53 wickets; and (4) Weir No. 2, 216 feet wide, which has 54 wickets. The distance between the centers of wickets on the weirs is 4 feet. The main sill of the weirs have the following references: Weir No. 1 is 2 feet and weir No. 2 is 3 feet above the sill of the navigable pass. This stepping of the sills was necessary in order to make the profile of the dam conform to the natural bed of the river. The perpendicular height of the navigable pass, from the sill to the crest of the dam, is 12 feet  $1\frac{1}{2}$  inches, while the height of the weirs are respectively 2 and 3 feet less, corresponding to the stepping of the sills referred to. The crest line of the navigable pass and weirs, which is a right angle to the river lock wall, is a continuous line (broken only by the bear-trap chute) and extending to the abutment on Davis Island, a total distance of 1,223 feet.

Seven years and nineteen days were consumed in the construction of the dam. Work was begun August 18, 1878, and completed October 7, 1885, when the dam was formally opened with a grand public demonstration combining civic and marine displays.

#### FOUNDATIONS.

In selecting foundations for the land and recess walls, the gates, the Chanoine dam at the head of the lock, and the river wall, borings were made to determine the depth of the rock. The land and recess walls are built on an argillaceous rock, which was excavated to the lower course of masonry; at a point 50 feet outside the



wall, the rock disappeared below the lowest point of the foundation. On the site of the river wall and dam proper no rock could be found at a depth of 15.17 feet in the former and 13.58 feet in the latter, below the gate sill. Instead of the rock a compact gravel was found. As these depths were deemed to be below any possible scour, it was decided to build on the gravel. The foundation for the river wall and dam proper was begun at the reference below the gate sill already given. This foundation (composed of concrete) was carried up, for the river wall, to a reference of 2.50 feet below the gate sill, making a depth of concrete of 12.67 feet, while the foundation for the dam was carried up to a reference of 1.58 below the sill of the dam, making a depth of concrete of 12 feet. In the foundation of the gate and of the Chanoine dam at the head of the lock, the bottom of the concrete was carried level at the reference of 15.17 feet below the gate sill, until it intercepted the rock at a point 50 feet outside the land wall. From thence to the land wall the depth decreased with the rising inclination of the rock, terminating at the land wall at a depth of 2.75 feet below the gate sill. From this depth to the full height it was finished with the timber gate sills and stone masonry.

The track sills on which the gate travels across the lock are built in the solid masonry, and are anchored deep in the concrete (or solid rock as the case may be) by bolts  $1\frac{1}{2}$  inches in diameter, placed at intervals of 4 feet and  $\frac{3}{4}$  inches. The lower ends of the bolts are provided with discs 18 inches square, which prevent the bolts being pulled through the concrete. As the rock (which has a rising inclination) is intercepted each successive bolt becomes shorter. To secure anchorage equal to those placed at the full depth of the concrete, the points of the shorter bolts were split, and secured by a fox wedge in a hole drilled in the solid rock. The shorter bolts are also provided with discs similar to those placed on the bolts having the full depth of concrete, in addition to the fox wedge.

Two large white oak timbers, placed 11 feet 6 inches apart and held in place by the bolts referred to, form the gate track sills. The upper sill is 18 inches square; the lower 23 by 25 inches. In the top of these sills a rabbet is cut, in which the track iron, 1 inch thick and 6 inches wide, is laid. The lower edge of the upper and the upper edge of the lower is protected by angle irons, preventing abrasion by the washing of gravel, sand, etc., caused by the wheels of steamers.

The floor of the gate foundation between the tracks (across the lock), which is 14 inches below the rail, forms a depression in which it was feared gravel and sand would accumulate in quantities which would interfere with the passage of the gate. Inspection of this after a winter's rest of the gate, during which time masses of ice passed over the sills, showed that the material collected did not interfere in the slightest degree with the operation of the gates. Furthermore, it was found that as soon as the lock was put in operation, the strong current which rushed between the tracks on its way to the lock filling and discharging valves located in the lower walls of the recesses, freed the cavity of all the material deposited there. The foundation of the lower walls of the recesses are deeper than those of the upper, while the gate tracks are on the same level. This depression of the lower so much below the upper wall, with the sloped pavement between them, is made to give a waterway to the lock filling and discharging valves which are in this wall.

#### CONCRETE MASONRY.

The portion of the foundation of the dam at the head of the lock and of the gates, that of the dam proper extending from the river wall to Davis Island, and the river lock wall, in all of which rock could not be reached at a reasonable depth, were built upon a concrete foundation, resting upon a hard gravel. The foundation of the dam at the head of the lock and of the gates follows the rock until a reference of 15.17 feet below the sill is reached. This level is preserved throughout.



## THE DAM.

The floor of the dam is a framed structure composed principally of 12 inch by 12 inch white oak timbers, framed in such a manner as to form a rigid combination. This framework was built in the foundation at the proper height, and the concrete built up around the timbers, thoroughly embedding them. The anchor bolts secured in the concrete foundation near the bottom pass up through the timbers, securing the framed structure to the foundation. The upper bolt is designed to resist any strain imposed upon the service bridge, either from actual work or in case of the bridge becoming clogged by driftwood. The lower bolt, of which there is one to each wicket, holds the dam in place. On the foundation thus prepared and composed of the concrete anchorage and framed structure referred to, the dam is secured. The wicket anchor bolts pass up through the timber structure and through a cast-iron box called the "horse box." This box forms the fastening for the lower axis of the horse, and is the chief connection holding the dam in position. Each wicket is composed of a horse, a prop, and a panel or shutter. The lower axis of the horse is secured to the horse box, the upper axis is attached to the panel near the center, around which the panel is free to rotate. The wicket when in position stands at an angle of  $20^{\circ}$  with the vertical top, inclined downstream, the lower end or breach resting against the main sill, while the upper end is supported at the upper axis of the horse by the prop, which rests against a cast-iron socket secured to the foundation, called a "hurter." Thus the dam is formed by a series of wickets extending across the river. Each wicket is 3 feet 9 inches wide with a space of 3 inches between adjacent wickets. This space is to prevent the wickets becoming fouled with each other, which would prevent their free movement. These spaces during very low stages of the river can be closed if necessary, thus saving the water to maintain the pool at its full height.

The arrangement by which each wicket is held in position and lowered to the bed of the river at will may be described as a sort of folding frame; all parts when lowered assume a horizontal position and lie below the main sill, insuring safety from steamboats or floating objects coming in contact therewith. The dam is operated by means of a service bridge and a maneuvering boat. The wickets of the weirs are maneuvered from the service bridge, those of the navigable pass from the boat. The service bridge is composed of a series of light trestles 8 feet apart with floors hinged to them and located immediately above the dam, extending on weirs 1 and 2 from the bear-trap chute to Davis Island, a distance of 428 feet. These trestles are so arranged that when not in use they lie in a recess or chamber in the foundation prepared for them. The floors hinged to them, forming connecting links between the trestles when in position, fold on top of the trestles when lying down. When the trestles are drawn up with the floors connected they form the framework of a bridge, extending from the bear-trap chute across the river parallel with the dam to Davis Island. When the service bridge and wickets of the dam are all down and it becomes necessary to raise the dam the first step is to draw up the trestle nearest the shore. This is done by means of a chain attached to it. The power employed is a trestle winch which runs on a track formed by the connecting floors of the trestle. When the first trestle is drawn up and its floor fastened it forms the first section of the bridge; the winch is then advanced on to this section, and the second trestle is drawn up, and its floor fastened. This operation is repeated until all the bridge is raised. The service bridge being raised, everything is in readiness to raise the dam. The operation of raising the dam is accomplished by another winch, called the wicket winch, the axis of which is parallel to the dam. To the breach of each wicket is attached a chain which is connected with the trestle and has been brought up with it from its recess in the



foundation. This chain is used to draw the wicket from its position when down to its position when raised. When the wicket is lying down all the parts assume a horizontal position; when the power is applied to the winch the wicket rises feathering to the current until it is drawn to its position, when the prop drops into the socket of the hurter, which makes a ringing sound. This is a signal for the workmen at the winch to stop; the chain is slacked up, and the prop rests firmly in its seat. The wicket, which so far has assumed a horizontal position, now requires to have the breach lowered to its bearing against the main sill in the foundation. When this is done the first 4 feet of the dam is completed, and the operation is repeated until all the wickets are raised. As before stated, only the weirs are maneuvered from the service bridge, the navigable pass being worked by a maneuvering boat. This boat, which is built of timber, is 50 feet long, 16 feet wide, and 3 feet deep, and is equipped with a steam engine and boiler used for raising the wickets, instead of a winch as on the service bridge, the engine being more rapid in its operations. The mode of raising the wickets by the boat is as follows: The boat is anchored to the river-lock wall, and from this position the first thirteen wickets are raised. This number of wickets gives a length of dam equal to the length of the boat, which is then placed broadside to the dam. The last wicket raised supports the boat for the next wicket. With the raising of each wicket the boat is advanced one, and so continued until all are raised. The engine is located in the center of the boat; the chain from the engine by which the wickets are raised changes its direction by passing over a sheave mounted at the bow of the boat, the end of which is attached to a hook, technically called a "maneuvering hook," by means of which the wickets lying in the bed of the river are caught and raised to their upright position.

To lower the dam the maneuvering boat is placed against the dam as in raising, except the position of the boat is reversed end for end, the top of the wicket is drawn forward about 9 inches, until the prop which supports the wicket drops off the second step of the hurter, when the wicket is released and the pressure of water against the wicket forces the prop into the downward channel of the hurter, and the wicket falls gently and without any shock into its position on the foundation in the bed of the river. In lowering the dam after all the wickets are down the service bridge is also lowered, thus giving an unobstructed channel.

#### LOCK GATES.

Steam power is employed to operate the lock gates. A portable engine and boiler is situated, one at each gate, the power of which is transmitted through a spiral drum on which is operated two chains, one attached to each end of the gate. By the reversible motion of the drum the gate is either opened or closed.

#### HYDRAULIC MACHINERY.

The lock filling and discharging valves are operated by water pressure operating hydraulic jacks, supplied from water tanks elevated to a minimum height of  $44\frac{1}{2}$  and a maximum of 60 feet. The water tanks are supplied by a pump in the river lock wall, which is operated by a 25-inch turbine wheel driven by the head of water created by the dam.

### 37. Philadelphia Harbor, before Improvement. Contributed by Maj. C. W. Raymond.

The model shows the condition of the harbor in 1891, before the commencement of the improvement, on a horizontal scale of 400 feet to 1 inch and on a vertical scale of 18 feet to 1 inch.



38. Philadelphia Harbor, as proposed. Contributed by Maj. C. W. Raymond.

The model shows the harbor as it will be after the completion of the rectification now in progress, on a horizontal scale of 400 feet to 1 inch and on a vertical scale of 18 feet to 1 inch.

MILITARY ENGINEERING.

FORTIFICATIONS AND COAST DEFENSE.

39. Battery, Depressing Gun. Contributed by Capt. J. G. D. Knight.

40. Battery, Lift Gun. Contributed by Capt. J. G. D. Knight.

The following remarks are by Gen. H. L. Abbot.

This class of mounting dispenses with the use of armor entirely, or at any rate restricts its use to a light bomb-proof roofing which may be sometimes used to stop fragments of shells and shrapnel balls. The gun and its platform are placed behind a suitable parapet, and by hydraulic power, with or without the aid of counterpoises, are raised and lowered at pleasure. When in the firing position the gun has all the capacity as to elevation and traverse afforded by the best barbette carriage, even, if necessary, being given a traverse of 360 degrees; but no sooner is its work done than it sinks out of sight and is loaded, so far as horizontal fire is concerned, in perfect safety.

Guns have been actually mounted upon this principle for several years at Cronstadt and at Alexandria, and the *Téméraire* and other armored vessels carry guns disposed in a similar manner. Gen. Duane, when president of the Board of Engineers, gave careful study to the subject and devised two types, one with and the other without counterpoises, which met with such favor before the Endicott board that the construction of fifty-four of them was recommended for the defense of the coast.

Lifts are usually restricted to the mounting of the 12-inch 50-ton gun, and are preferred for medium heights where a wide traverse is required. They would serve an excellent purpose as the chief defense of secondary ports, where the depth of water in the channel will not permit the entrance of vessels carrying a more powerful armament than the 12-inch gun.

This mode of mounting possesses so many and such incontestable merits that a few details may prove interesting. The two types devised by Gen. Duane differ only in the mode of applying power to the raising and lowering of the platform. They have in common a substantial parapet to resist the fire of the heaviest gun which can be brought against them. Usually the front of this parapet would be of earth, but near the guns it must be of massive masonry, presenting only a horizontal surface to the fire of the enemy. The crest is broken by semicircular recesses, 50 feet in diameter, to receive the guns, which are placed at a minimum distance of 74 feet apart. The centers of these semicircles are 5 feet in front of the crest, giving a horizontal angle of fire of 180 degrees. The arrangements behind the parapet dispense with the use of traverses—a very great advantage, as their absence destroys the usual clew to the position of the guns. The latter are mounted on any form of low center-pintle barbette carriage, which is supported by a circular platform 26 feet in diameter. This platform, when in the firing position, forms part of the masonry floor of the recess, the reference being 6 feet below the crest. This floor extends unbroken to the rear for 50 feet from the center of motion of the gun. Covered by it are two tiers of casemates for magazines, shell-rooms, etc.; and in



front of them on the side of the gun is a long gallery, parallel to the crest, for communications, hydraulic machinery, etc. The circular platform rests on a trussed staging, and can be lowered 14 feet to the loading position. The muzzle of the gun in the firing position extends well over the crest. After the recoil, if not already there, it is traversed to the front, where, within an angle of 60 degrees, the flooring is cut away to form a recess to receive the muzzle in lowering. Loading is done from a fixed position, the usual shot-lift supplying the ammunition in front of a hydraulic rammer to force it home in the gun.

#### 41. 16 Mortar Battery, Abbot's. Contributed by Capt. J. G. D. Knight.

The following remarks of Gen. Abbot are quoted in reference to this battery:

In order that the projectiles shall fall sufficiently near together to make the fire effective, it is essential that the mortars shall be massed, thus constituting, as it were, a single piece. Four mortars may be placed in one pit, and by disposing four of these pits symmetrically around a common center very convenient arrangements for serving are secured. A compact battery containing 16 mortars logically results from this reasoning, and that number is suitable for the command of a single officer.

The radius of the circle is fixed by the following considerations: On the one hand—the lateral and longitudinal separation of the pits must be sufficient to afford space between them ample for magazines, loading rooms, and bomb-proof cover for the garrison. On the other hand, the extreme distance between pits must be limited to the extreme dispersion of the projectiles of a single mortar, else there will be an area of safety in the middle of the field of fall. Lateral dispersion being much less than longitudinal dispersion, this condition fixes a much narrower limit for admissible separation of the pits in a direction across the plane of fire than in a direction parallel to that plane. Indeed, in the former direction the extreme limit can hardly be avoided; but in the latter it is easy to secure a decided overlapping of the rectangles.

These conditions are fulfilled when the centers of the outer mortars in each pit lie on a circle 150 feet in radius, the extreme lateral separation being 140 feet, and the extreme longitudinal separation being 265 feet.

The arrangements in the battery are simple. One long bomb-proof extends parallel to the usual plane of fire, with debouches into each pit near its extremities; the magazines, shell-rooms, engine-rooms, etc., are placed under the cross embankment, with communications opening into the middle of the central bomb-proof. The firing will all be done by electricity from the bomb-proof, permanent leading wires to the mortars being laid in advance; all the work of loading, except the actual insertion of the shells in the mortar, will also be done under cover; the cannoniers will be exposed only when loading; and, lastly, nothing but accident can bring a hostile shell to interrupt the steady prosecution of the firing.

The service of such a battery in action would be something like the following: The captain would take his station at a point from which he could see the enemy engaged at work, as, for example, at countermining in our mined channel. From this point and a position-finder he would determine the elevation, charge, and azimuth for a trial shot. Giving his orders by telephone, he would watch the splash of the shell, and, estimating the deviation, would give orders for the second shot accordingly. Having succeeded in dropping one shell in close vicinity to the enemy, he would order the whole battery to adopt the same elevation, charge, and azimuth, and to fire by volleys of 4 or of 16 mortars, as seemed best.

#### 42. The Bridge Equipage. Pontoon. Contributed by Col. J. M. Wilson.

The United States bridge equipage is composed of reserve and of advance-guard trains. The former are intended to accompany large bodies of troops in the field,



and are provided with the material necessary for the construction of bridges of sufficient capacity to pass large armies with their heaviest trains over rivers of any size and rapidity.

The advance-guard equipage is intended for the use of light troops, such as advance guards, cavalry expeditions, etc. It is organized, both as regards material and carriages, with a view to rapidity and movement. At the same time it is capable of furnishing a bridge which will fulfill all the requirements of troops on such service.

#### RESERVE EQUIPAGE.

*Organization.*—This equipage is divided into trains, each of which is composed of four pontoon divisions and one supply division. Each division is accompanied by a tool wagon and traveling forge.

Each pontoon division is complete in itself, containing all the material necessary for constructing a bridge of eleven bays, or 225 feet in length.

Each of these divisions is subdivided into four sections, two of which are pontoon, and two abutment sections; the former contain three pontoon wagons and one chess wagon; the latter, one pontoon, one chess, and one trestle wagon each.

The pontoon section contains the material for three bays, and should never be subdivided. The division may be increased or diminished at pleasure, by changing the number of its pontoon sections.

The carriages are loaded as follows:

Each pontoon wagon contains 1 pontoon, 7 long balks, 1 anchor, 1 cable, 5 oars, 2 boat-hooks, 20 lashings, 6 rack-sticks, 1 scoop-shovel, 2 small scoops, 1 ax, 1 hatchet, 1 bucket, and 20 pounds of spun yarn.

Each trestle wagon contains 7 long balks, 7 trestle balks, 1 trestle complete, 2 abutment sills, 2 coils of 3-inch rope.

Each chess wagon contains 60 chess.

The supply division is provided with articles necessary to replace material lost or worn out, such as balk, chess, spare parts of carriages, a few complete carriages, etc.

#### ADVANCE-GUARD EQUIPAGE.

*Organization.*—The trains of this equipage are composed of 4 pontoon divisions, each of which consists of 8 pontoon, 2 chess, and 2 trestle wagons.

The load of the pontoon wagon consists of 7 balks, 16 chess, 2 side frames, 1 cable, 1 anchor, and a pontoon chest containing 1 pontoon cover, 14 transoms, 5 paddles, 2 scoops, 2 mallets, 20 lashings, 2 boat-hooks, 1 scoop-shovel, and 8 rack-sticks.

The chess wagon contains 50 chess and 2 spare pontoon covers.

The trestle wagon carries 14 balks, 1 trestle complete, 1 abutment sill, and 1 coil of 3-inch and 1 of 1-inch rope.

The forge is forge A of the Ordnance Department.

When necessary this load may be reduced by transferring a part of the tools and coal to a forage wagon.

The pontoon wagon carries all the material necessary for constructing a complete bay. The division may, therefore, be increased or diminished by one or more pontoon wagons without disorganizing it. When a forced march is to be made and it is desirable to lighten the loads the chess may be removed from the pontoon wagons, the rope from the trestle wagons, and the load of the chess wagons be reduced to 40 chess. The number of the latter wagons in this case must be increased to 5.

A detailed description of the equipage and a review of the considerations which led to its adoption, together with a historical sketch of its efficient service during the civil war, may be found in the "U. S. Bridge Equipage and Drill," published by the Engineer Department of the U. S. Army, and contained in the Engineer Library in this exhibit.



43. Gun Carriage, King's Disappearing. Contributed by Lieut. Col. W. R. King.

The following is a brief description of this carriage as it now stands, taken from a report of Col. King to the Endicott Board in 1886.

The pintle block, traverse circles, traverse wheels, props, and chassis are like the old ones, excepting that the chassis is longer and slopes 20 degrees to the rear, the front end being raised about 7 feet above the pintle block.

The pintle is hollow, 10 inches inside diameter, and 1 inch thick.

The counterpoise is made, for convenience in handling, in disks 1 foot thick, and moves in a well under the pintle block. The pulleys in the counterpoise and chassis are grooved for four wire ropes. These ropes are made of six strands, with nineteen steel wires to the strand, and a core of soft iron wire. The ropes are of equal length, and can be fitted with iron knobs at the factory, so as to require no adjustment after they are put in place. One end of each rope is held by a socket at the front of the pintle block, and the other by a socket hinged to the under side of the top carriage, near its front end.

The top carriage is so made that when the rear truck wheels are thrown "in gear" the weight of the gun is thrown upon the front wheel also—in fact over two-thirds of the weight then comes upon the front wheels; but when "out of gear" nearly the whole weight slides. The throwing into and out of gear is done by two or more men turning the hand-wheels at each side and just below the breech of the gun; and the weight of the counterpoise is such that when in gear the gun will run up into battery; but when sliding, as during recoil from firing, the top carriage will remain wherever it stops.

The elevation of the gun, in "pointing," is given by the same hand-wheels, the operation being controlled by the gunner, as shown in the plate, while two other men turn the wheels.

In loading, Nos. 1 and 2 stand upon a platform inside the chassis, and the shot is rolled to them from a rack along the breast-height wall. Both elevation and horizontal direction can be given while the gun is under cover of the parapet.

In actual service the gun is carried back under cover for loading by the recoil, and "into battery" by the counterpoise, but for purposes of drill the top carriage is run "from battery" by the endless chains at the side, actuated by the cranks near the rear end of the chassis.

The original carriage, differing only in certain details from that here represented, was first mounted at Fort Foote, Maryland, and afterward at Battery Hudson, New York Harbor. It was tested at various times during the four years beginning February, 1869, by boards of engineers, ordnance, and artillery officers.

Caliber of gun tested, 15-inch; weight of gun, 50,000 pounds; weight of shot, 450 pounds; charge, 100 pounds mammoth powder; weight of counterpoise, 47,900 pounds; slope of chassis, 20°; elevations, from  $-3^{\circ}$  to  $+30^{\circ}$ ; horizontal traverse  $130^{\circ}$  plus; number of cannoniers, 6 to 8; minimum time of loading with undrilled men, 2 minutes; number of rounds fired with 100-pound charges, 145; maximum recoil, 17.5 feet; descent of gun, 6 feet.

44. Gun Carriage, proposed by Col. De Russy, Corps of Engineers, 1835.

This model was on exhibition in the Engineer section of the War Department exhibit at the Centennial Exposition in 1876, and the following description, taken from the official report, is introduced here:

This carriage was devised about the year 1835.

The top carriage rests in front on the axle of a pair of large eccentric wheels, the rear end resting on small wheels running on curved wooden braces.

In the firing position the axle of the eccentric wheels is in its highest position, and the small wheels on the highest point of the braces. As the gun recoils, the



axle runs to its lowest position, and the truck wheels to the bottom of the braces, the recoil being partly taken up by a counterpoise of metallic spokes on the side of the main wheels opposite the axle, and partly by frictional appliances.

The gun is run into battery by a windlass and chain.

It will be seen that this carriage embodies the principle which Capt. Moncreiff afterwards employed in the construction of his depressing carriage.

45. Mine, Military. Contributed by Col. J. M. Wilson.

46. Mines, Submarine, Triple Group. Abbot's system, with connections and appliances. Contributed by Lieut. Col. W. R. King.

There are exhibited three submarine mines arranged to represent a triple group for actual service in the defense of a harbor. A "triple group" is one of seven similar groups constituting a grand group of twenty-one mines.

A cable armored with steel and containing seven copper cores, insulated from the armor and from each other, leads from the post of the operator in the casemate to the position of the grand junction box. Here the several cores are connected by carefully insulated joints to the cores of seven single-conductor cables leading outward to seven triple junction boxes, only one of which is here shown. At the triple junction boxes the cables are connected by insulated joints to three other single conductor cables leading out to the mines. Thus there is an uninterrupted metallic circuit from each core of the multiple cable at the casemate to the three mines constituting the triple group, and there are seven triple groups or a "grand group" of twenty-one mines operated through each multiple cable leading from the casemate. The connections are such that the triple groups are electrically separate from each other, but the several members of each triple group are connected from the triple junction box inward through a single circuit to the casemate, viz, through one single-conductor cable and a particular core of the multiple cable. The return circuit from each mine to the casemate is through certain mechanisms in the interior of the torpedo to the torpedo case and thence through the water to earth. These mechanisms taken together with the operating box in the casemate are such that at the option of the electrician the blow of a vessel upon a mine may explode its charge of dynamite or simply register a signal in the casement that a mine of such a group has been struck. In the latter case, the electrician may, if he desire, fire the triple group to which belongs the mine from which the signal has been received.

In the group here shown there are three types of mines; a 32-inch spherical buoyant mine, a 46-inch elongated buoyant mine, and a 28-inch ground mine. The buoyant mines are of 10-pound open hearth steel,  $\frac{1}{4}$  inch thick, and the ground mine is of cast iron  $\frac{3}{4}$  inch thick. The spherical mine is made in two hemispheres ribbed at the equator, and afterwards the two parts are welded together. Before being accepted from the makers it is filled with water and subjected to an internal pressure of 120 pounds per square inch without developing leakage. The elongated type is for use in strong currents where greater buoyancy is required. It is of the same material as the spherical pattern, and is like it in its details. The buoyancy of the spherical mine in sea water, when loaded, is about 230 pounds; that of the elongated mine is about 900 pounds. The ground mine is cast in one piece, and in form it is a segment of a sphere; it is for use in shallow channels. The electrical mechanisms by which the ground mine is operated are contained in the buoy attached to it. This buoy is similar to the buoyant mines in form and external attachments, but its interior arrangements are different, since it does not contain the explosive. The buoyant mines are attached to anchors by iron mooring ropes, the lengths of which are adjusted according to the depth of water in which the mines



are planted. The anchors are of cast iron, and are of two sizes, weighing 500 and 1,000 pounds respectively, the heavier weights being required in rapid currents. The ground mine acts as the anchor for its buoy.

The electricity used in operating the mines is generated by chemical batteries situated in the casemate. Of these batteries there are two, the signal and the firing battery. The former, used in making electrical tests during the planting of the mines and after the mines are laid for detecting and locating leaks in the cables or joints, is composed of usually six sulphate of copper cells set up in series, and has an E. M. F. of about 6 volts, and an internal resistance of about 3 ohms. When the mines are adjusted for judgment-automatic firing, the current from this battery operates through the system of mines at all times, not being of sufficient strength through the high resistance of its circuit to explode the fuses in the mine, but actuating the electrical magnets which give the signal in the casemate when a mine is struck. The firing battery consists of cells of the Lechanché type arranged in boxes of ten cells. Ten of these boxes are ordinarily used in operating a grand group of mines. The cells have each an E. M. F. of about  $1\frac{1}{2}$  volts and an internal resistance of about three-tenths of an ohm, and are coupled in series.

47. The Sims Edison Fish Torpedo. Contributed by Lieut. Col. W. R. King, Corps of Engineers.

The Sims-Edison fish torpedo is a metal boat propelled and steered from shore by electricity; its object is to carry under water a charge of dynamite to the hull of a hostile vessel and there explode it below the water line.

It consists of two principal parts:

First. The torpedo proper, or boat, which, when in actual use, is submerged about 4 feet; and contains the explosive, the propelling, steering, and firing apparatus.

Second. The float which buoys the boat and, when in use, shows just out of water. It carries two uprights surmounted by rubber balls, which indicate to the operator on shore the position of the torpedo and the direction in which it is moving.

The torpedo proper is a copper cylinder tapering to a point at each end; the front end has a steel point; the rear carries the journal for the propeller-shaft which lies in the axis of the cylinder. For convenience in handling, and repairing internal mechanism, the boat is made in four sections, which are fastened together by an interrupted screw connection. The forward section contains the explosive (250 pounds of dynamite) and the proper firing fuse; the second contains a drum of cable by which electricity is transmitted from shore; the third contains the electric motor, and the stern section carries the steering magnets and relay, and supports the propeller and rudder.

For operating this torpedo two electric currents are necessary. A current of between 30 and 35 ampères and of about 250 volts pressure is required to drive the propeller and to furnish the force for moving the rudder. A smaller current, known as the steering current, controls the rudder by means of a relay which directs the main current to one or the other of the two large steering electro-magnets.

In order to carry these two currents safely the cable must have two cores securely insulated from each other and from the water. The inner core occupies the axis of the cable and carries the steering current; the outer and larger one surrounds the inner, and both consist of a number of very small copper wires laid together. This reduces the resistance of the cable and at the same time makes it very flexible; great flexibility is essential for easy winding on the drum and easy paying out as the torpedo moves from shore.

A rear compartment of the cable section carries the firing relay; by reversal of the main current the fuse in the forward compartment is detonated and the charge of dynamite thereby exploded. Provision is also made for firing automatically when the nose of the torpedo strikes.



The float is also of copper, is supported on the boat by strong steel struts and made with a section adapted to great buoyancy. To prevent its sinking in case it is pierced by shots it is stuffed tightly with cotton.

The uprights carrying the balls are furnished with spring hinges in order to permit passage under a boom or similar obstruction. To further facilitate passage of obstructions the forward steel strut is inclined upward to the rear and made with a thin edge.

The fish torpedo on exhibition carries 2 miles of cable, and its motor is constructed to make a speed of about 10 miles per hour. A larger boat has been made and is now at Willets Point awaiting further tests of its capabilities.

The latter boat carries 2 miles of cable, requires a current of 35 to 40 amperes and 1,500 volts, and in the last test made reached a speed of 18.1 miles per hour. It also successfully passed a large spar about 8 inches in diameter, which was anchored across its course, but instead of diving under the spar it made a clean cut through it.

The cable has been improved of late, and in the last one made a pressure of 2,000 volts failed to cause a leak. This cable has been wound and unwound about twenty times, and is still perfectly serviceable for trial runs.

48. Turret, Gruson. Contributed by Col. H. L. Abbot.

48a. Block House. Contributed by Lieut. Col. W. R. King.

Representing a form used in the late war for defending bridges or other isolated points. Designed by the late Col. William E. Merrill, U.S. Engineers. The model was made by Sergt. Joseph Miller, then of the Battalion of Engineers.

#### ADDITIONAL MODELS.

49. Orograph. Contributed by Lieut. Col. W. R. King, Corps of Engineers.

A machine for making a profile of irregular ground by simply passing over the line to be delineated. This machine was made for the U. S. Engineer Department in 1853 by Messrs. Whetstone & Sellers, then of Cincinnati. The latter gentleman, Mr. George Escol Sellers, now some eighty years of age, is living in Chattanooga, Tenn. Mr. Whetstone is living in Covington, Ky.

The description of this instrument is contained in the following letter, dated September, 1853, to Col. S. H. Long, Corps of Topographical Engineers, by Mr. Wm. F. Beach, Assistant Engineer. It is furnished with the machine by the contributor, Lieut. Col. W. R. King, Corps of Engineers.

"The instrument which you have directed me to examine is called an oro-graph (mountain writer). It consists of two substantial carriage wheels—10 feet in circumference, following each other in the same track—with an interval of 4 feet, and supporting on one side a box 39 inches long, 15 inches deep, and 8 inches wide, containing mechanism balanced on the other by a circular cistern 24 inches in diameter and one-half an inch thick placed vertically and containing mercury. The instrument is held upright and guided by plow handles attached before and behind.

"The objects it is intended to accomplish are to draw upon paper an accurate profile of the ground over which it is rolled, thus furnishing the engineer with all the results of a survey excepting the courses and topography.

"The principles upon which it is constructed are those of the perambulator, operating in conjunction with a lever maintained continually in a horizontal position by floating upon a cistern of mercury. This lever is 24 inches in length and half an inch thick, with floats attached to each end, and has free motion in a vertical plane on a horizontal axis within a cistern half filled with mercury and adapted to its size.



"The principles upon which the reduction of surface distance to true measurement is accomplished are, that if the surface measure of any portion of ground be called radius the true horizontal distance will be the cosine of the angle of inclination or grade of the surface, and the difference of level will be the sine of the same angle, and that an arm or crank may move in a slot or elongated hole in such a manner as to give it a motion corresponding to such sine or cosine.

"The machinery by which these principles are made to operate consists of a circular disk revolving by connection with the perambulator with a velocity proportionate to the surface passed over, and of an adhesion wheel whose plane is perpendicular to the plane of the disk, and whose circumference is tightly pressed against it, and so receives motion from it, while kept at a distance from its axes, varying as the cosine of the inclination or grade of the surface.

"This varying motion of one wheel against the face of another is effected by an arm from the axis of the horizontal lever moving in a slot, which, together with a parallel motion, sustains the adhesion wheel against the circular disk from which it derives its motion.

"The adhesion wheel moving according to the true horizontal distance communicates motion by means of an endless screw and by ratchet work to wheels which register all distances up to a hundred miles.

"Another arm from the axis of the horizontal lever moving in a slot perpendicular to the former one, varies the position of two adhesive wheels pressed against two circular disks in a manner similar to the former but varying in proportion to the sine of the angle of inclination.

"The two adhesion wheels just mentioned both revolve in the direction and with the same axes and contain within these axes, one a male and the other a female screw; these screws are so arranged that if the adhesion wheels both revolve with the same velocity, by being kept at the same distance from the axes of the circular disks by means of a lever acting through the medium of the slot, the screws, although loose in its wheel, will neither advance nor recede, but a difference of level, moving both the lever and the slot and bringing one adhesion wheel nearer and the other further from the axis of the disks, and therefore causing difference in velocities, will make the screw which carries the pencil of altitude advance or recede as long as difference of level causes difference of velocities in the adhesion wheel and the screws which move with them.

"The arrangement by which the paper is made to pass under the two pencils (one to mark the surface and the other the base line and station) is at once suitable and ingenious; the two rollers upon which the paper is wound keep it tightly straightened by a tendency to motion in opposite directions communicated to them through friction and from the main shaft, while drum rollers geared to the true horizontal motion deliver the paper under the pencils with the smallest expenditure of force.

"The pencil of altitude moves an inch for every 50 feet change of level, and the paper is drawn under the pencils at the rate of an inch for every 500 feet in distance.

"The true horizontal distance can be read to tenths of a foot, and the surface distance to every 10 feet.

"The machinery by which so many complicated movements are produced is substantial and well adapted for service, capable of adjustment in every part, and not liable to get out of order if well used; the cistern containing the mercury is entirely of metal, the framework securely trussed and bolted.

"The perambulator wheels are well made of the toughest materials, banded with steel tire; the handles by which the instrument is propelled and managed are similar to those of a plow and are hinged to the framework near the center of gravity, adding much to the stability of the machine.



"In order to test the orograph in field work an undulating road in the vicinity of Louisville was selected and a straight line surveyed of 1 mile in length, staked out, and the levels taken in the usual manner, a profile of which with the level marked at every 100 feet is annexed to this report marked A. \*

"The orograph was then placed on and rolled along the line producing the profile\* marked No. 1; readings of both horizontal distances and levels were taken at every 400 feet of the former survey, and are marked at their appropriate places on the profile. On arriving at the end of the line it was found that from inaccuracy in the use of the chain with which the first survey had been made, 40 feet was lacking of a mile, which distance was made up by the orograph and numbered 16. The instrument was then reversed and rolled back to the first station, making the profile\* and note marked 2.

"The instrument not proving to be in perfect adjustment the screws were changed, and the approach of evening not permitting the taking of observations it was rolled to the end of the line. Reversed and returned to the first station the profiles\* with all the notes taken marked upon them will be found marked Nos. 3 and 4.

"The following tabular statement, by bringing all the observations together under the eye, gives a good idea of the working of the instrument :

| CHAIN AND LEVEL. |                 |         | OROGRAPH.       |         |                 |         |                 |         |                 |         |
|------------------|-----------------|---------|-----------------|---------|-----------------|---------|-----------------|---------|-----------------|---------|
| Stations.        | Dis-<br>tances. | Levels. | FIRST TRIAL.    |         | SECOND TRIAL.   |         | THIRD TRIAL.    |         | FOURTH TRIAL.   |         |
|                  |                 |         | Dis-<br>tances. | Levels. | Dis-<br>tances. | Levels. | Dis-<br>tances. | Levels. | Dis-<br>tances. | Levels. |
| 1.-----          | 0               | 200.0   | 0               | 200.0   | 0               | 206.6   | 0               | 200.0   | 0               | 202.5   |
| 2.-----          | 400.0           | 196.9   | 397.8           | 197.4   | 397.8           | 203.2   | -----           | -----   | -----           | -----   |
| 3.-----          | 400.0           | 199.2   | 399.2           | 199.8   | 396.7           | 206.0   | -----           | -----   | -----           | -----   |
| 4.-----          | 400.0           | 210.7   | 395.5           | 210.7   | 396.6           | 216.5   | -----           | -----   | -----           | -----   |
| 5.-----          | 400.0           | 215.2   | 396.5           | 214.8   | 396.2           | 220.5   | -----           | -----   | -----           | -----   |
| 6.-----          | 400.0           | 213.1   | 396.5           | 213.4   | 396.3           | 218.0   | -----           | -----   | -----           | -----   |
| 7.-----          | 400.0           | 201.0   | 396.5           | 202.0   | 396.3           | 206.5   | -----           | -----   | -----           | -----   |
| 8.-----          | 400.0           | 203.6   | 397.7           | 204.8   | 399.4           | 209.0   | -----           | -----   | -----           | -----   |
| 9.-----          | 400.0           | 207.1   | 395.5           | 205.2   | 394.4           | 212.7   | -----           | -----   | -----           | -----   |
| 10.-----         | 400.0           | 190.8   | 395.8           | 193.5   | 395.6           | 197.1   | -----           | -----   | -----           | -----   |
| 11.-----         | 400.0           | 209.1   | 396.5           | 210.6   | 396.8           | 213.2   | -----           | -----   | -----           | -----   |
| 12.-----         | 400.0           | 223.8   | 396.7           | 224.6   | 396.8           | 225.8   | -----           | -----   | -----           | -----   |
| 13.-----         | 400.0           | 196.5   | 395.5           | 200.0   | 405.5           | 200.7   | -----           | -----   | -----           | -----   |
| 14.-----         | 400.0           | 188.5   | 396.7           | 192.5   | 386.8           | 193.0   | -----           | -----   | -----           | -----   |
| 15.-----         | 80.0            | 184.0   | 80.0            | 188.5   | 80.2            | 188.6   | -----           | -----   | -----           | -----   |
| 16.-----         | -----           | -----   | 51.8            | 188.1   | 61.8            | 188.1   | 5287.1          | 188.2   | 5287.9          | 188.2   |

"The results of the last mile and back on the same track show by reference to the foregoing statements a difference in the 2 miles of 2.5 feet in level and of but 0.8 feet in horizontal distance, being a variation of but 0.4 feet in horizontal distance to a mile.

"A result containing so little error and so much more accurate than could be obtained with the chain justifies me in pronouncing the instrument sufficiently accurate as an indicator of horizontal distances.

"An effort was afterwards made to ascertain to what degree of accuracy the instrument was capable of being adjusted and of marking intermediate distances and levels. With this object in view and for the purpose of getting better ground, the initial point of the line was moved 320 feet back, and a line of 5,500 feet run by the orograph with stakes placed 500 feet apart. On arriving at the end of the line the instrument was reversed and returned to the beginning, profiles\* and notes of which are subjoined, marked Nos. 5 and 6.

"Changing the adjustment of the instrument once more it was again made to go the same mile\* and repeat, the results of which are numbered 7 and 8, and No. 8 not put in ink in order to show the profile\* as it comes from the instrument.

\* Profiles and notes omitted—not available.



"The following table affords comparison between the different runs of the last four miles:

| STATIONS.                 | FIFTH TRIAL.    |         | SIXTH TRIAL.    |         | SEVENTH TRIAL.  |         | EIGHTH TRIAL.   |         |
|---------------------------|-----------------|---------|-----------------|---------|-----------------|---------|-----------------|---------|
|                           | Dis-<br>tances. | Levels. | Dis-<br>tances. | Levels. | Dis-<br>tances. | Levels. | Dis-<br>tances. | Levels. |
| 0 -----                   | 0               | 200.0   | -----           | 197.0   | 0               | 200.0   | 0               | 202.7   |
| 1 -----                   | 500.0           | 212.8   | -----           | 210.2   | 500.0           | 213.2   | 499.2           | 216.0   |
| 2 -----                   | 500.0           | 205.4   | -----           | 203.2   | 500.0           | 206.4   | 499.0           | 208.8   |
| 3 -----                   | 500.0           | 221.0   | -----           | 218.8   | 500.5           | 222.0   | 501.1           | 224.6   |
| 4 -----                   | 500.0           | 225.0   | -----           | 223.1   | 499.5           | 226.0   | 499.3           | 229.2   |
| 5 -----                   | 500.0           | 212.6   | -----           | 210.1   | 502.6           | 214.4   | 503.0           | 216.4   |
| 6 -----                   | 500.0           | 213.6   | -----           | 212.1   | 501.6           | 215.7   | 502.0           | 218.1   |
| 7 -----                   | 500.0           | 217.1   | -----           | 216.0   | 500.4           | 219.8   | 501.2           | 222.2   |
| 8 -----                   | 500.0           | 199.5   | -----           | 199.0   | 500.5           | 203.6   | 500.6           | 205.3   |
| 9 -----                   | 500.0           | 228.0   | -----           | 227.5   | 500.5           | 232.1   | 500.4           | 234.0   |
| 10 -----                  | 500.0           | 208.5   | -----           | 208.5   | 501.4           | 214.6   | 502.4           | 215.0   |
| 11 -----                  | 500.0           | 197.6   | -----           | 197.6   | 493.6           | 204.7   | 493.6           | 204.7   |
| <i>Surface distance :</i> | 5520.0          |         | 5520.0          |         | 5520.0          |         | 5520.0          |         |

"By a reference to the notes tabulated above you will observe that they show an extreme variation at an intermediate station of 1.2 feet vertical and of 2.3 feet horizontal measurement, although at the end of the mile it is much below that limit.

"As a probable explanation of these results I would remark that the adjusting screws having been moved at the end of each 2 miles, the profiles and notes do not bear close comparison with each other, which, added to the fact that the instrument had received only a workshop adjustment, gives reasonable hopes that future trials in the field will give a much better result.

"And I might further remark that machinery performing so many different operations is of course somewhat complicated and of necessity has many adjustments, so that in a limited number of trials opportunity is not allowed to become sufficiently acquainted with the effect of the different adjustments to change at the first trial the proper screw.

"I would therefore respectfully recommend that the inventor be employed to make more extended experiments and observations under the immediate supervision of yourself or of the Department in order that these discrepancies may be detected and corrected before the instrument is ordered in the field.

"In reference to the quantity of work which the instrument is able to do, I would state that a mile without stopping was run in 18 minutes, and a mile, taking notes every 500 feet, in 35 minutes; and from observations in regard to its speed and manner of working I feel assured that with a horse to do the pulling from 10 to 20 miles might be accomplished in a day.

"As to its practical utility I am of opinion that if it were used in connection with a theodolite to determine the bearings and check and correct the levels, while the orograph filled in the measure and profiles, sufficient accuracy might be obtained to admit of its use on turnpike and even railroads until the work was put under contract.

"I can not conclude this report without bearing testimony to the ingenuity with which the inventors have overcome the many obstacles which have prevented others from reducing to practice the idea of such a labor-saving machine."

#### 49a. Zenith Telescope. Contributed by Lieut. Col. W. R. King.

Invented by Capt. Andrew Talcott, formerly of the U. S. Corps of Engineers, about 1853. This is believed to be one of the first, if not the first, instrument of the kind ever made for determining latitude by Capt. Talcott's method, which has long been recognized as the most accurate method for that purpose known to astronomers.



## B.—Enlarged Photographs, Framed.

## RIVER AND HARBOR IMPROVEMENTS.

50. Agate Bay Harbor, Michigan; Lake Superior. Contributed by Capt. W. L. Fisk.
51. Boston Harbor, Point Allerton. Contributed by Lieut. Col. S. M. Mansfield.
52. Boston Harbor, Entrance of the Narrows. Contributed by Lieut. Col. S. M. Mansfield.
- Views of Buffalo Harbor Improvement, New York. Contributed by Maj. E. H. Ruffner, Corps of Engineers, in charge:
53. Outer Harbor. View from breakwater, looking northeast. Entrance to Buffalo Creek, which is the inner harbor, on the left, near lighthouse.
54. Breakwater, north end. Concrete superstructure built in 1887-'89.
55. Trestle for track used in transporting concrete. Built on superstructure cribs.
56. North concrete mixer, erected upon the parapet of the breakwater, with timber shields for protection from the seas.
57. North concrete mixer. Showing platform on piles for storage of concrete material.
58. Breakwater. Showing double track, double cable railroad for transporting concrete for building superstructure. View from north mixer looking south.
59. Breakwater. Same as 58, from south mixer looking north.
60. Concrete mixer receiving a charge.
61. Filling charging box with concrete material.
62. Concrete blocks for foundation. Showing method of building up in alternate sections of 50 feet, or one crib length of superstructure.
63. Dump and grip cars.
64. Timber crib-work extension at south end.
65. Timber crib-work extension at south end. Showing commencement of superstructure.
66. Molds for forming parapet and banquette of concrete superstructure.
67. Cumberland River Improvement, Tennessee. Steamboat landing at foot of Broad street, Nashville. Contributed by Lieut. Col. H. M. Robert.
68. Calumet River, dredging in. Contributed by Capt. W. L. Marshall.



69 and 70. Panoramic views of Chicago Harbor. Contributed by Capt. W. L. Marshall.

The following history of this improvement has been prepared by Mr. G. A. M. Liljencrantz, assistant engineer.

Chicago Harbor is composed of three principal parts, viz:

(1) *The River*, which with its branches and slips has a dock frontage of some 70 miles, and is known as the "Inner harbor." This portion has been improved, and is maintained by and at the expense of the city of Chicago, except at its mouth, which was originally improved by the United States Government.

(2) *The Outer Harbor Basin*.—This, in conjunction with the shore breakwater built by the Illinois Central Railroad Company, is formed by the easterly and southerly breakwaters and the South Pier, all built and maintained by the United States Government.

(3) *The Harbor of Refuge*, or anchorage ground in deep water. This has been secured by the construction of the "exterior breakwater" by and at the expense of the United States Government.

*The Inner Harbor*.—The existence of a harbor at Chicago dates back six decades, the first work of improvement having been done in 1833. Prior to this time no vessels could enter the river, which then made a sharp bend southward near the present site of the Illinois Central depot and entered the lake in the neighborhood of Twelfth street, or near where said railroad is now building its new passenger depot, being nearly 1 mile south of the bend, and its mouth was closed up by a sandbar.

The first improvement consisted in the making of a straight cut through the extended sand spit between the river and the lake, and the construction of a pier about 1,000 feet in length north of said cut and running in a direction about east by south.

The south pier was built later on. Each of these piers was thereafter extended lakeward from time to time, as fast as occasion required and the necessary appropriations of funds would allow. The directions of the piers varied somewhat to the northward or southward, especially that of the north pier, as suggested by the noted effects of the completed work on the lake bottom at the ends of the piers.

In 1852 a pierhead was built at the then outer end of the north pier, as a site for a light-house, which, however (in 1869), was constructed on piling about 50 feet farther northward. In 1865 this north pier was extended 450 feet farther eastward and in a more northerly direction, by and at the expense of the city of Chicago.

These works constitute practically the lakeward end of the Inner Harbor, which was thus completed in 1865.

The piers along the channel, forming now the docks or retaining walls for the adjoining property back of them, which property was made partly by natural accretion and partly by artificial means, by corporations or private parties, have since been occupied by such persons for commercial purposes, and have been maintained almost exclusively by them.

*The Outer Harbor Basin*.—Maj. J. B. Wheeler, Corps of Engineers, in a letter dated November 30, 1869, recommended the formation of an Outer Harbor basin as an anchorage ground for vessels during severe weather, by the further extension of the south pier (in which, however, an opening was to be left for communication with the river entrance), the construction of a breakwater running 4,000 feet from the outer end of the extended south pier, in a southerly direction, and by a closing pier from the south extremity of the breakwater to the shore at the foot of Van Buren street.

This project was approved and work commenced thereon in September, 1870, but was so far modified in 1878 that the present southerly breakwater, with an opening



750 feet in length left between it and the easterly breakwater, was substituted for the closing pier, thus increasing the basin area very materially.

The finishing of the southerly breakwater in 1880 completed the project for the Outer Harbor basin, as far as the inclosing boundaries were concerned. Dredging to a depth of 15 feet was done in the eastern portion of the basin and a dock line was officially established, fixing the limit between the harbor area proper, or anchorage ground, and the space reserved for the ultimate construction of wharves and slips.

The projected benefits of the basin to the lake commerce have not however been realized fully as yet, owing to the protracted litigation over the ownership of the lake front, the submerged lands, and riparian rights, which has prevented the construction of any wharves or similar improvements south of Randolph street.

The severe northerly and northwesterly gales prevalent in this locality made the entrance to the harbor very difficult and dangerous at times, and this fact suggested (in 1873) the extension of the north pier a distance of 400 feet in advance of the north end of the easterly breakwater. Although an improvement on previous conditions it still proved insufficient in securing a safe entrance for vessels.

*The harbor of refuge, or anchorage ground in deep water.*—To make the river entrance perfectly safe and at the same time secure a harbor of refuge or an anchorage ground in deep water, where vessels could get much needed protection while awaiting the abating of northerly gales, a project was submitted by Maj. G. J. Lydecker in 1878 for the construction of the "exterior breakwater," over 1 mile in length, and located about midway between the harbor entrance and the old waterworks inlet crib.

The project was approved. Work commenced in 1883 and was completed in 1889.

The object sought has been accomplished. Vessels can now safely enter the harbor in any kind of weather, and a safe refuge and shelter in deep water with good anchorage ground of clay is afforded vessels when required.

*Available depth of channel.*—With the rapidly increasing lake commerce have come increased dimensions in the various classes of vessels, which in turn has demanded a gradual increase in the channel depths in the various harbors on the Great Lakes.

A map showing a survey of Chicago Harbor in 1857, the oldest one on file in this office, shows a channel depth of from 13 to 15 feet, but with a bar at the mouth covered by only 9.5 to 10 feet of water.

In 1864, according to official reports, the channel had a depth of from 10 to 12 feet, with but 8 feet of water over the bar at the mouth.

A map of August, 1865, shows a channel of from 13 to 14 feet near the mouth with not more than 6 feet over the sand bar, which then ran in a southerly direction for a distance of about 1,000 feet and was about 150 feet in width.

When in 1869 Maj. J. B. Wheeler submitted his project for an outer basin, as before stated, it includes a provision for a depth of "over 12 feet of water" on one-third of the basin area (which contained 275 acres) and but 7 feet over the balance.

In 1876 a 15-foot channel was available at the mouth of and for some distance up the river, and dredging is now being made (March, 1893) to secure a depth of not less than 16 feet below low water of 1847 or nearly 18 feet below the mean lake level.

*General character of improvements.*—The modes of construction and plans for general arrangements applied in improving the harbors of the Great Lakes, have been periodically modified as suggested by experience.

The effects of lake and river currents, combined with prevailing winds and other causes, on the lake bottom, have been carefully noted and studied by the officers of the U. S. Engineer Corps for many years.



The chief points of study and observation have been those relating to the location of piers with reference to the natural shore line and to the general plans and details of the structures employed.

Crib work has been found the most substantial, durable, and convenient for piers, when in the lake, and has been exclusively used in Chicago Harbor.

Originally cribs were sunk directly on the sand bottom and filled with stone, part of which was allowed to pass through a grillage, at the bottom of the crib, on purpose to secure a reliable foundation. The cribs were then left to settle until the next following season, when the superstructure, always made continuous, was built over them.

The settling and tilting of the cribs was generally irregular and frequently quite considerable, making the subsequent work difficult, expensive, and unsatisfactory in various respects. To remedy this other methods were devised successively, such as, first, the formation of a rubble foundation, leveled off at an elevation where it was expected to be undisturbed by the action of waves, to support the cribs; next, the suspension of the cribs in the desired position by iron chains, fastened to guide piles; while the crib was so suspended stone was allowed to pass through the grillage bottom first, forming a foundation underneath and then filling up the crib itself. Finally a form of pile foundation was devised, consisting of piles driven in rows on the proposed crib site and cut off in a horizontal plane about 2 feet above the lake bottom.

This method furnished a firm and rigid support for the cribs and prevented the vexatious settling and tilting almost entirely, and in consequence the building of the superstructure was followed shortly after the sinking of the cribs. In places where deep water and exposure to rough weather would make the driving and cutting off of piles hazardous and impracticable, as at the exterior breakwater in Chicago Harbor, a foundation of heavy stones has proved the most satisfactory.

*Extent of commerce.*—As a commercial seaport Chicago harbor has steadily increased in importance and to a degree that borders on the marvelous.

The magnitude of the present lake commerce at this port is indicated by the following brief extracts from data for the year 1892 furnished by the collector of customs for this district:

Arrivals: 9,073 vessels of an aggregate net tonnage of 4,798,241; and clearances, 9,252 vessels, with an aggregate of 4,972,215 tons.

Chicago has twenty-seven grain elevators, with an aggregate capacity of 30,075,000 bushels, and a commercial fleet, owned in the city, composed of 372 vessels and craft of different kinds, with an aggregate net tonnage of 63,579.29 tons. Chicago is claimed to handle the greatest amount of grain and produce of any port in the world.

View of Coos Bay, Oregon, Improvement. Contributed by Capt. T. W. Symons, Corps of Engineers, in charge.

71. Outer end of jetty, pile-driver, train with rock.
72. Revolving hydraulic pile-driver, swinging pile into position.
73. Self-righting cars.
74. Rock ready to be dumped and mattress ready to be lowered.
75. Jetty.

Survey of Upper Columbia River. Contributed by Capt. T. W. Symons, Corps of Engineers.

76. The survey party.
77. Typical Indian scene.



Improvement of Columbia River at Cascades, Oregon. Contributed by Maj. T. H. Handbury.

78. Site of Cascades Lock. Upper end of the Cascades.

79. The Cascades of the Columbia River, 165 miles above the mouth. River navigable to this point.

80. Cascades Lock during construction. Near view of south chamber wall, December 15, 1891.

81. Cascades Lock during construction. Back view of south chamber wall, showing timber and pole bracing for holding concrete form.

82. Cascades Lock during construction. Constructing north abutment, lower lock gate, and lower guard gate.

83. Cascades Lock during construction. Same as 82, looking east. September 16, 1891.

The improvement of the Columbia River at this point is planned to overcome the rapids that occur where the river flows through a gorge in the Cascade Mountain range. The fall in the river here is from 36 feet to 45 feet in a distance of  $4\frac{1}{2}$  miles, depending upon the stage of water. Besides the removal of boulders in the bed and projecting rocks in the banks, the plans of improvement contemplate the construction of a canal 3,000 feet long and 90 feet wide, and the accompanying lock with its accessories. The lock is to be 462 feet long and 90 feet wide, and will have a lift of 15 feet at high water and 24 feet at low water, with a depth over miter sill of 8 feet at low water. The lock walls are to be composed of Portland cement concrete, faced on the canal side with basalt blocks cut from the boulders found in the vicinity, and at points where greater strength is desired, with granite.

The lock is to be filled through culverts, for which the forms and centers for the arches are shown in some of the views at different stages of the work. The estimated time of filling is nine minutes.

The gates, with frames of steel, will be maneuvered by hydraulic power.

The plan of improvement contemplates the present provision for navigation up to a 20-foot stage, with arrangements for adding structures in the future to accommodate navigation at higher stages. Agreeably to this plan, the upper gates of the present lock will become the lower gates of the high-water lock hereafter to be built.

The slope and dimensions of the walls are as follows:

The height of the walls of the lock chamber above foundations is 49 feet. "The face is vertical down to 2 feet above low water, and is finished below that level with a toe having a slope of 4 on 1. This toe, without interfering with the interests of navigation, materially strengthens the wall by widening the base where most needed. The back is vertical at top and bottom with a connecting slope 3 on 2. In construction, this slope will be stepped. The top width is taken at 8 feet for stability against shocks. The bottom width is 26.5 feet, exclusive of the toe, and 29.75 feet with the toe. The heaviest pressures come when the lock is empty; and the foundation is 844.3 square feet, including the toe and excluding the culvert.

"*Walls of the upper lock-gate recess.*—These walls are designed to support gates for use also as the lower gates of the high-water lock. The proposed height is 18 feet above the walls of the low-water lock. On account of the introduction of the culverts into the lock walls, it is necessary to carry them down to the same foundation level as the chamber walls. They must also have a top width of 13 feet for the gate engines, and below the bottom of the gate they extend forward



8.11 feet to the line of the chamber walls. The width is 33.11 feet at the bottom, with a perpendicular face at the ends. In the center the face is also vertical, but is stepped in horizontally 8.11 feet at 22 feet above the foundation, practically forming, as far as concerns the stability of the walls, a toe with slope of about 2.7 an 1. The height of the walls is 66 feet."

These quotations are made from a report made in 1891 by Lieut. Edward Burr, Corps of Engineers, then in local charge, to Major Handbury, and published in annual report of the Chief of Engineers for 1891, part 5, page 3347 *et seq.*

Reference is invited to this report for details of the plans of the work and for full discussions of the considerations leading to the adoption of various details of the lock.

The views exhibit the construction of the work at different stages and some of the appliances devised for mixing, handling, and depositing the large masses of concrete.

84. Connecticut River, Connecticut, Mouth of. Contributed by Col. D. C. Houston.

View looking north along the west jetty about half tide. The jetties east and west were begun in 1873. Length of west jetty 2,550 feet. Of east jetty 2,316 feet.

They are of heavy riprap, to be finished to top width of 6 feet at  $8\frac{1}{2}$  feet above mean low water. The jetties were designed to maintain and shelter the entrance channel to Connecticut River. They have been successful in maintaining the depth of nearly 12 feet, where only 7 feet existed before.

85. Connecticut River, Connecticut, Mouth of. Contributed by Col. D. C. Houston.

View looking southwest from east jetty, showing the west jetty and light-house at its outer end.

Views of Improvement of Coosa River, Alabama. Contributed by Capt. P. M. Price, Corps of Engineers.

86. Lock No. 4, during construction. View taken from east bank, showing (in order) narrow-gauge railway and tram for transporting stone from quarry, 2 miles distant; partly built cofferdam for lock; cable way with trolley; partly built dam; partly built masonry abutment; tower for cable way; and partly built earth levee.

87. Lock No. 1, looking upstream.

The Coosa River is formed by the junction of the Oostenaula and Etowah rivers in Northwestern Georgia, near Rome. It flows through the mineral region of northeastern Alabama, and joins the Tallapoosa River 18 miles above Montgomery, Ala. The Coosa and Tallapoosa rivers form the Alabama River, which empties into Mobile Bay. The Oostenaula is navigable for a distance of 105 miles above Rome, Ga. The Coosa River is 315 miles long, and the Alabama River (including the lower end, called the Mobile River) is 356 miles long. The combined length of the system is 776 miles, all of which affords good facilities for water transportation by river steamers and barges, except the portion of the Coosa River between Greensport and Wetumpka, Ala., a distance of 142 miles, which has an average slope of nearly 3 feet per mile, and is much obstructed by rock reefs. This stretch of river is now under improvement by the United States Government, by a system of locks and dams, of which the three upper locks have been completed, opening 26 miles



to navigation ; two are under construction, and twenty-six have not yet been begun. The low-water discharge of the Coosa River at Wetumpka, Ala., is 5,796 cubic feet per second.

88. Improvement of Delaware Breakwater Harbor. Delaware Breakwater, showing the Breakwater, Ice breaker, and top of substructure now being constructed. From Light-house at east end of Breakwater looking west. Contributed by Maj. Chas. W. Raymond.

See A, Models, 3.

89. Delaware River Improvement. East Dikey at Bulkhead Bar, showing two large steamships passing through the channel at low water. View from the New Jersey shore, looking west. Contributed by Maj. Chas. W. Raymond.

90. Lewes, Del., Iron Pier at, showing parts of Breakwater and Ice Breaker in the distance. View from the shore looking northwest. Contributed by Maj. Chas. W. Raymond.

See A, Models, 2.

91. East River. Hell Gate; Explosion of Flood Rock. Contributed by Lieut. Col. G. L. Gillespie. View of East River at Hell Gate, showing effect of the great explosion at Flood Rock October 10, 1885, taken about two seconds after explosion.

See A, Models, Nos. 9, 10, 11, 12, and 13.

Fox River Improvement, Wisconsin. Contributed by Maj. C. E. L. B. Davis.

92. First lock at Kaukauna.

93. Lower dam at Appleton.

94. Dam at Little Chute.

95. Combined lock at Little Chute.

96. Winter view of locks Nos. 2, 3, 4, and 5 at Great Kaukauna.

97. Fox River, Wisconsin. Grignon Rapids. Contributed by Maj. J. F. Gregory.

View shows United States dredges Nos. 2 and 3, tugboats *Boscobel* and *Gen. G. K. Warren* ; also steam drilling plant at work deepening the channel by blasting and dredging rock. Holes 2 inches in diameter are drilled to a depth of 6 to 7 feet into the rock (10 holes covering an area of about 300 square feet), the holes are each charged with about 2 pounds of *Ætna* powder, and the charges simultaneously exploded by means of electricity. The rock is then removed by dredges.

French Broad River Improvement, Tennessee. Contributed by Lieut. Col. H. M. Robert.

98. Dam above old chute, Hanging Rock Shoals. Looking upstream.

99. Dams at foot of Seven Island Shoals. Looking downstream.

Views of Galveston Harbor, Texas. Contributed by Maj. C. J. Allen.

100. Section of South Jetty.

Section of shore branch of south jetty, looking north towards Fort Point light-house. Gulf of Mexico on the right ; Galveston Bay on the left. Length of south



jetty completed, 19,400 feet; length of south jetty partly completed, 5,194 feet; total, complete and incomplete, March 1, 1892, 24,597 feet.

101. Section of South Jetty. Looking towards city of Galveston from point near Fort Point light.

The city of Galveston is built upon the northeasterly end of Galveston Island, which is about 28 miles long by an average width of about  $1\frac{1}{2}$  miles and separated from the mainland of Texas by a channel known as West Bay, and having an average width of  $2\frac{1}{2}$  miles. Opposite the northeasterly end of the island is Bolivar Peninsula, which is a part of the mainland. North of Galveston Island and Bolivar Peninsula is Galveston Bay, which has a surface area of about 450 square miles. Along the northerly part of the city of Galveston and facing Galveston Bay is the Galveston Channel, the depth of water in front of the wharves being from 22 to 30 feet. The tidal flow of Galveston Bay, to and from the Gulf of Mexico, is almost entirely through what is known as Bolivar Channel, 8,600 feet in width, and lying between Bolivar Peninsula and Fort Point, the latter a low sandy extension of Galveston Island. The depth of water in Bolivar Channel is 30 feet and upward for about  $1\frac{1}{4}$  miles gulfward of Bolivar Peninsula.

The obstructions to the entrance to Galveston Harbor have consisted of an inner and an outer bar. The former, at an entrance to the Galveston Channel leading to the wharves had, before the work of improvement was undertaken, a depth of but 13 feet of water, and at times even less. The outer bar lies about 4 miles gulfward of the southerly point of the peninsula. The depth upon this bar, before the work of improvement was undertaken, was 12 feet.

The works for improvement of the entrance to the harbor, as planned in 1886 and now in progress, are to consist of two jetties of rock to be built to a height of 5 feet above mean low tide and to extend, if necessary, to the 30-foot depth in the Gulf of Mexico. Dredging, as auxiliary to the jetties, will also be resorted to if found necessary. The jetties to have their origins, respectively, at Galveston Island and Bolivar Peninsula. They are known as the north and south jetties, the latter having its origin at Galveston Island. Their aggregate lengths, if extended to the 30-foot contour or depth in the Gulf of Mexico, will be about 62,000 linear feet, or nearly 12 miles.

The top and slopes of the jetties are to be protected by large blocks of stone, the blocks increasing in size as the jetties progress to the crest of the bar, beyond which the blocks are to weigh not less than 10 tons each.

The object of the jetties is to concentrate the flow upon the bars and thus deepen the channels so as to admit the passage of the deepest draft ocean vessels.

The south jetty has been completed for about 31,000 linear feet, or nearly 6 miles, and partly built for several hundred feet further gulfward, or to within a few hundred feet of the outer crest of the outer bar, and preliminary work has begun upon the north jetty.

The effect of the south jetty, so far as built, has been to increase the depth on the inner bar to 21 feet and that on the outer bar to 14 feet.

All the depths here given are those at mean low tide.

The average rise of the tide above the plane of mean low tide on the outer bar closely approximates 2 feet; the high tides, at times, are considerably in excess of 2 feet.

Illinois River Improvement. Contributed by Capt. W. L. Marshall.

102. La Grange Lock.

103. Kampsville Lock, during construction. General view.



104. Kampsville Lock, during construction. Showing arrangements for laying stone on lock walls.

Views of Great Kanawha River Improvement, West Virginia. Contributed by Col. W. P. Craighill.

105. Lock and Dam No. 7, during construction.

106. Lock and Dam No. 4, during construction.

107. Inside first section No. 7, for navigable pass.

108. Inside first section No. 7, completed.

109. Lock and Dam No. 4, after completion.

110. Coal barges and towboats.

111. Coal barges and towboats.

112. Interior of Lock No. 7, during construction.

113. Cofferdam for Lock No. 4.

114. Towboat and barges in Lock No. 6.

115. Towboat and barges passing out of Lock No. 6.

For description of the works illustrated by views Nos. 105 to 115 inclusive see A, Models, Nos. 22 and 23.

Louisville and Portland Canal. Contributed by Lieut. Col. G. J. Lydecker.

116. Enlargement at lower end, showing excavation and new canal wall nearly completed; old wall still in place.

117. Enlargement at lower end, showing full width of enlarged canal with old wall partly removed.

119. Old locks. Built 1830.

120. New locks. Looking downstream, showing guard gates and head bay.

121. New locks. Showing upper lock as seen from middle gates.

122. General view of locks as seen from below. Engineer office, lock manager's residence, and other buildings pertaining to canal shown on high point to left of locks.

123. Lower lock, as seen from Tail Bay.

The following history and description of this improvement has been compiled verbatim from annual reports for 1878 and 1892 of the officers in charge to the Chief of Engineers.

A mass of rocks in the bed of the Ohio River opposite Louisville, Ky., forms a series of obstructions known as the Falls of the Ohio. The bed of the river at this point has a fall of 26 feet in a distance of about 2 miles, four-fifths of this fall being within a distance of about 1 mile.

The falls or rapids are impassable during a large portion of the year; and at all other times, except when the river is very high, navigation over them is difficult and dangerous.

As early as the year 1802 the expense and delay attending the reshipment of freight around the falls from the Lower to the Upper Ohio had become so serious that numerous plans were proposed for overcoming the obstruction, but no active measures were taken until the year 1825, when a stock company obtained a charter from the legislature of the State of Kentucky authorizing them to construct a canal around the Falls of the Ohio within the State of Kentucky.



This canal was completed and the first boat passed through December 22, 1830, though many subsequent improvements were made. As originally constructed the canal was 1.9 miles long, 64 feet wide, and had at its lower end three lift locks (combined), each 198 feet long between miter posts, with available length of 185 feet, 50 feet wide, with lift of  $8\frac{2}{3}$  feet.

In 1830, when the canal was completed, its dimensions were thought to be sufficient for all time, but gradually the size and model of steamboats were so changed that in 1852 but fifty-seven one-hundredths of the tonnage engaged on the western waters could pass through the locks.

The aid of Congress was invoked from time to time, and in 1842 an elaborate memorial was presented, setting forth the inadequacy of the Louisville and Portland Canal and asking for an appropriation for its enlargement.

The evident necessity for an enlargement, as well as the demand of the public for a reduction of the heavy rates of toll, induced in many of the stockholders the opinion that the canal should be held by the United States, enlarged, and made free. With a view to this the Kentucky legislature, in January, 1842, upon petition of the Louisville and Portland Canal Company, amended the charter to admit of liquidating the stock and ultimately making the canal free.

In February, 1844, the Kentucky legislature amended the act of January, 1842, by enacting that in the event of the United States becoming the sole owner of the canal, the jurisdiction of the Commonwealth over the said canal would be yielded up to the Government of the United States, and no reports would be required to be made to the general assembly. It was in accordance with this amendment that the Government finally took possession of the canal.

When the necessity for an enlargement became apparent and the tolls became a burden on western commerce, it was natural for those interested in the river traffic to look to Congress for relief; for not only was the canal a part of a national highway, but the United States, being a large stockholder, had derived a profit from the tolls collected.

Despairing of Government aid, the directors, in 1856, at the suggestion of the Secretary of the Treasury, prepared plans for enlarging the canal, and an act was obtained from the Kentucky legislature authorizing the directors to appropriate the revenue and pledge the credit of the company for the enlargement of the canal. On the 24th of May, 1860, Congress ratified this authority with the proviso that the president and directors of the company should in no way use or pledge the faith or credit of the United States, and that when the enlargement was completed and paid for no more tolls should be collected than an amount sufficient to keep the canal in repair and pay necessary expenses of superintendence and management.

The directors immediately raised money by issuing bonds, purchased land, and engaged the services of Mr. T. R. Scowden, a distinguished hydraulic engineer, under whose direction detailed plans were prepared and the work of enlargement was commenced. The war of the rebellion so increased the cost of labor and material that the original estimates were greatly overrun, and in 1866, after expending \$1,825,403, work was necessarily suspended.

By joint resolution of Congress approved March 29, 1867, the Secretary of War was directed to cause to be made, by an officer of the Engineers, surveys and estimates for a ship-canal around the Falls of the Ohio on the Indiana side of the river; also to cause to be made by the same officer estimates for completing the Louisville and Portland Canal on the Kentucky side of the river.

From these examinations and surveys it was concluded that whatever other work might be necessary, the Louisville and Portland Canal should be immediately completed. Upon the recommendation of the Chief of Engineers, U. S. Army, approved by the Secretary of War, an allotment was made in 1868 for continuing the enlargement of the canal.



There was allotted to this work from time to time, from appropriations by Congress, including \$100,000 appropriated in 1875, \$1,463,200, making the total cost of this work, including original cost of canal, the amount expended by the old company and the amount expended under the direction of the Corps of Engineers, about \$4,250,000. Of this amount the Government furnished, including bonds assumed, about \$2,500,000, the balance being paid for by a tax on the river commerce in the form of tolls.

The present canal leaves the Ohio River above the falls at a point opposite Eighth street, runs in a westerly direction in front of the city of Louisville, and enters the river opposite Sand Island, a short distance above Portland, Ky., and below all permanent obstructions to navigation.

An apron dam 1,800 feet long facilitates the entrance to the canal and prevents boats being drawn on the rocks at the head of the falls. A crib wing dam extends from near the head of the apron dam along the crest of the falls with suitable openings for passing boats.

The length of the canal, including the new branch, is  $2\frac{1}{4}$  miles, and the widths are, at upper entrance 400 feet, at turnout basin  $176\frac{1}{2}$  feet, and throughout the canal  $86\frac{1}{2}$  feet. The depth of the water varies with the stage of the river, the minimum being 6 feet.

The south bank of the canal and the greater portion of the north bank are protected by stone walls founded on the solid rock through which the canal is excavated. From the top of these walls, after leaving a berme of from 15 to 30 feet in width, earthen parapets with slopes of 2 on 1 rise to a height of 44 feet above the canal bottom and 1.3 feet above the highest known flood.

Near the head of the canal is a set of guard gates used to shut out the water in case repairs are necessary. The locks are all placed at the lower or western end of the canal. The old set have been remodeled by converting the three chambers into two of a size sufficient for passing all stern-wheel boats running during ordinary stages of the water, and all sizes of flatboats and barges. The new locks form the outlet of a short branch leaving the canal a short distance above and entering the river a short distance below the old locks. The new locks are two in number (combined), 80 feet in width, 372 feet in length between miter posts, with an available length of 335 feet; the lifts are 12 and 14 feet.

For what was considered good and sufficient reason, when the gate machinery was first devised man power was adopted, but steam power, more economical and as easily regulated, has been applied.

Rises in the river which submerge the lower locks are frequent, and occasionally both locks are entirely under water. At such times the sediment deposited is enormous. This deposit, in a greater or less degree, is continually going on, and a steamboat, dredges, and dump scows, all belonging to the canal, are constantly in use, removing from the canal and locks every year nearly 100,000 cubic yards.

The time of lockage varies with the stage of the water. When the river is high and but one chamber is used, a lockage occupies about half an hour, but at ordinary and low stages, when both chambers are used, one hour is necessary. With an extra force of men, the time of lockage for coal tows through two chambers can be reduced to about 45 minutes. The opening or closing of a set of gates occupies about 7 minutes, and the filling or emptying chambers about 11 minutes.

The improvements now in progress are designed to give increased facilities for passing the Falls of the Ohio via Louisville and Portland Canal. They consist in enlargements at the upper entrance to the canal and immediately above the locks at the lower end in such manner as to form capacious basins, or harbors, at those points.



The project for the enlargement at the head of the canal was inaugurated in 1883 and modified in 1890, as recommended in the report of the Board of Engineers, dated January 28, 1890. The general width of the canal before enlargement was 90 feet; when the work is completed, the width for a length of 2,400 feet will be from 210 to 325 feet; immediately to the eastward of this enlargement of the canal proper a basin about 800 feet wide and 2,200 feet long will be constructed, which will be closed by a bear-trap structure 800 feet long on the west and by a concrete dam 2,800 feet long on the north. The execution of this project requires, as its principal features, the excavation of about 325,670 cubic yards of solid rock and 270,000 cubic yards of earth, the construction of about 5,200 linear feet of new canal wall and masonry dams, containing in all about 26,000 cubic yards of masonry, and the removal of about 6,200 linear feet of old canal wall, dikes, and timber dams.

The other portion of the improvement, viz, the canal enlargement above the locks, has been carried on in accordance with the project authorized in the Annual Report of the Chief of Engineers for 1887, the purpose being to construct at that point a basin wherein boats may lie and tows may be properly formed before or after passing the locks, without interfering with navigation through the canal. The work approximately estimated as necessary to this end was the excavation of about 124,000 cubic yards of earth, 13,000 cubic yards of rock, the construction of about 5,200 cubic yards of masonry wall, and the removal of 1,050 feet of old canal wall on the north side. The result will be a basin at the lower end of the canal 1,500 feet long, with a width varying from 210 to 250 feet.

Statistics of traffic and commerce indicate the extensive river tonnage directly interested in the substantial and complete improvement of the Falls of the Ohio. They show a traffic of 7,939 boats passing this point during the past fiscal year [ending June, 1892], carrying 2,172,661 tons of freight. The annual average for the past eleven years is 7,025 boats, with about 2,500,000 tons of freight. Of coal alone the amount passing the falls to points below during the past six years has averaged 1,731,308 tons annually.

124. Ludington Harbor, Michigan. Contributed by Maj. William Ludlow.

Views of Marquette Harbor, Michigan. Contributed by Capt. W. L. Fisk.

125. Same; from the outside.

126. Same; from the inside.

127. Same; from the breakwater.

128. Manistee Harbor, Michigan. Contributed by Maj. William Ludlow.

St. Marys Falls Canal and Locks. Contributed by Col. O. M. Poe.

129. Canal and Lock of 1881. Showing vessels bound down and waiting to lock.

130. Canal and Lock of 1881. View from north wall of lock looking east. Vessels bound up waiting to lock.

131. Canal and Lock of 1881, showing vessels bound up waiting to lock, August 3, 1890.

132. Opening lower gate.

133. West bound steamer leaving lock.

134. East bound steamer leaving lock.



135. Repairing accident to lock, August 2, 1890. View in lock chamber. Preparing to remove broken valve at lower gates. Vessel with pumping plant below lower guard gates.
136. Repairing accident to lock, August 3, 1890. View from lower guard gates looking west. Showing lock chamber empty and men at work removing broken valve.
137. Repairing accident to lock, August 3, 1890. View from north bank of canal looking southeast, vessels in canal waiting for passage. Movable dam on the right.
138. Repairing accident to lock, August 3, 1890. View from north wall of lock looking east.

See A, Models, No. 25:

139. Michigan City Harbor, Indiana. Contributed by Maj. William Ludlow.
140. Muskegon Harbor, Michigan. Contributed by Maj. William Ludlow.
141. Milwaukee Bay and outer harbor. Contributed by Maj. C. E. L. B. Davis.
- Upper Mississippi River Improvement. Contributed by Maj. A. Mackenzie.
142. Blasting in mid-channel, Lock Island Rapids.
143. Interior of Des Moines Rapids Dry Dock.
144. Mississippi River; snag boat Macomb at work. Contributed by Maj. A. M. Miller.
145. Mississippi River. Pile-drivers at work. Contributed by Maj. A. M. Miller.
146. Near Pine Bend, Minnesota.
147. Below Ninninger.
148. Below Keithsburg, Minn.

See A, Models, Nos. 31, 32, 33, 34, and 35.

#### SNAG BOATS FOR WESTERN RIVERS.

The two snag boats shown by photographs in this exhibit [see also Nos. 166 and 169] are types of the most modern constructions for use in the improvement of navigation in the Missouri and Mississippi rivers. The snag boat *J. N. Macomb* was the first of the kind built; she was constructed about 1875 at a cost of \$180,000 and exhibited by model, drawings, and photographs at the International Exhibition, Philadelphia, 1876.

A very complete description of her is given in Maj. Heap's report on the International Exhibition, and the following facts and extracts are taken chiefly from that report:

"The boat differs from those that preceded her in being single instead of double hulled and in being made of iron instead of wood. She is also 20 feet longer. These



changes allowed a much stronger and more substantial boat to be constructed on a much less draft of water than the old ones, and facilitated a better and more economical arrangement of the machinery."

Her main engines are about 556 H. P.; her hoisting engines capable of a dead-lift of about 75 tons. She is also furnished with capstans for light lifts—15 tons—and with two steam saws. Her length is about 175 feet, beam 62 feet, and draft, when loaded, 3 feet 4½ inches. Her work has been chiefly on the Mississippi River below the mouth of the Missouri.

The *C. R. Suter* is a light-draft snag boat with a steel hull and designed to do service in the Missouri River at any stage above that giving a depth of 30 inches. She was completed, except her equipment and final steam fitting, in the fall of 1886, but owing to lack of funds she could not be made ready for service until March, 1889, when she was put into commission under the direction of the Missouri River Commission. Her length is about 187 feet, beam 52 feet.

Both boats are of the pattern known as the "twin bow" or "boot jack" pattern. The well between the bow is spanned, near the front, at the water's edge by a collection of massive timbers sheathed with iron. These timbers are called the butting beam and tie the two bows together as well as furnish a broad working platform. The main shears, made of iron and capable of lifting 200 tons, stand immediately above the butting beam, and back of the shear legs are the steam capstans, two on each fork of the hull.

"Snags almost invariably point down stream. They are inclined at various angles, depending upon their length and the depth of water, and their roots are usually embedded, often very solidly, in the sand or mud of the bottom."

The snag is generally pulled out by the hoisting engines, the limbs, knots, trunk, and roots being sawed into short pieces as they come up; these pieces are allowed to float away or, if they will not float, to sink in some out of the way place. Occasionally the roots of a snag have to be loosened by using the boat as a battering ram and delivering heavy blows with the butting beam.

The commerce of these rivers has been greatly benefited by the work of snag boats and the wreck of steamers by running into snags, formerly a frequent occurrence, is now rarely heard of. New snags are constantly being brought to view by the annual changes in the river bed, and continual vigilance is therefore necessary to keep the river clear of them.

Mississippi River Shore Protection Work. Contributed by Capt. C. McD. Townsend.

149. Showing head of mattress.
150. Grading bank at foot of mattress.
151. Weaving and stiffening the mattress.
152. Making mattress; mattress nearly ready for lowering.
153. Sinking the mattress.
154. Loading the sunken mattress.
155. Protecting upper bank.
156. Sinking subaqueous mat, Plum Point, Mississippi River. Contributed by Capt. S. W. Roessler.

Estimates of material: Average size of mat, 1,000 feet long by 200 feet wide. Brush,  $1\frac{4}{10}$  cords per lineal foot. Poles,  $\frac{2}{10}$  cord per lineal foot. Stone to ballast and sink mat, about  $1\frac{1}{3}$  cubic yards per lineal foot.



## MISSISSIPPI RIVER COMMISSION WORKS.

The following description has been furnished by Capt. C. F. Palfrey, Corps of Engineers, secretary of the Mississippi River Commission.

*Personnel.*—"Seven commissioners, three of whom shall be selected from the Engineer Corps of the Army, one from the Coast and Geodetic Survey, and three from civil life, two of whom shall be civil engineers, \* \* \* one of the commissioners appointed from the Engineer Corps of the Army to be president of the Commission."

*Duty.*—"To direct and complete such surveys of said river between the Head of Passes near its mouth to its head waters as may now be in progress, and to make such additional surveys, examinations, and investigations, topographical, hydrographical, and hydrometrical, of said river and its tributaries as may be deemed necessary by said Commission, \* \* \* to take into consideration and mature such plan or plans and estimates as will correct, permanently locate, and deepen the channel and protect the banks of the Mississippi River, improve and give safety and ease to the navigation thereof, prevent destructive floods, promote and facilitate commerce, trade, and postal service." \* \* \*

## METHODS AND RESULTS.

*Surveys and examinations.*

The general survey is based on a secondary triangulation, and a tertiary connecting therewith lines of bench marks at 3-mile intervals (extending across valley for 3 miles, or to bluffs if nearer) and on lines of precise levels.

Detailed topography, showing 5-foot contours on bottom lands and 20-foot contours on bluffs, is carried over a belt extending 1 mile on each side of the river. Soundings are taken for sections at intervals of 250 meters or less for special features and continuously along channels.

Field instructions for these works are given in Annual Report, 1891, pp. 3474-3485.

Triangulation and B. M's have been carried from Head of Passes to 10 miles below Illinois-Wisconsin State boundary, a distance by river of 1,696 miles.

Ordinary B. M. is shown, consisting of molded tile, 18 inches by 18 inches by 4 inches (buried mark) with iron pipe 4 inches by 4 inches, bearing iron cap, to project above surface; also drawing showing special marks of triangulation and precise level B. M's.

Lines of precise levels have been carried from Biloxi, Miss., and from Head of Passes to New Orleans; thence near the river to St. Paul, Minn., with branches from St. Paul to Duluth, connecting with Lake Superior, and from Savanna, Ill., to Chicago, connecting with Lake Michigan; a total length of 2,280 miles.

Topography and hydrography have been carried from Donaldsonville, La., to Head of Des Moines Rapids, 10 miles above Keokuk, Iowa, a distance by river of 1,315 miles.

The survey is platted on scale 1 : 10,000, all letters and figures printed from type by hand stamp, topographical signs printed from electrotyped rollers and retouched by hand. One chart is shown on wall, and the implements and method of printing on table.

The plats are photolithographically reproduced, diminished one-half. An atlas is shown on table. Charts Nos. 31-42 are entirely from hand work; Nos. 43 to 69 have lettering by type and topographical signs by hand; Nos. 3-30, and 101-116 are produced as above.



From the detail charts, topographical maps are drawn on scale 1 inch to 1 mile, and photolithographed on same scale. One original is shown on wall, and atlas of reproduction on table.

The original survey from mouth of Ohio to Donaldsonville, La., having been made between 1879 and 1883, a resurvey of the bank line was made in winter of 1891-'92, to determine the changes by erosion and bank building. The results, platted on printed inch-mile maps, afterwards paraffined, are shown in blue print.

Borings have been made at various points for determination of structure of the banks. Samples of material arranged in glass tubes to represent characteristic strata are shown on wall.

Gauges have been established and maintained at 18 stations, and the records of these and of 41 other gauges tabulated and printed. Shown in seven pamphlets.

The corresponding hydrographs have been platted and are shown in atlas of blue prints. The continuous hydrographs of certain selected stations during twenty years are included in same atlas.

Discharge observations have been systematically kept up and their computed results printed. Shown in five pamphlets.

#### CHANNEL WORKS AND BANK PROTECTION.

The general plan adopted by the Commission for the improvement of the river from the mouth of the Ohio to the mouth of Red River contemplates the reduction of the low-water width to about 3,000 feet, by means of permeable dikes, behind which artificial banks shall be formed by deposit, and the preservation of the natural curves of the river by revetting caving banks, together with the construction of levees as a secondary means of maintaining the regimen of the river. Below Red River, by reason of the depth of water and the comparative stability of the banks, no works of contraction are required.

In both classes of work the unstable foundation, the great force of the river, and the great difference, both in volume and direction, of flow during high and low waters, presented a difficulty for which no precedent was on record. The earlier forms of construction were tentative as to the holding power of the bottom, the necessary strength of structure, and the extent of work that could be safely undertaken with a given amount of money. The types evolved by experience are shown.

*Contraction works.*—Permeable dikes of three rows of piling (piles single or in groups, according to depth and current) driven through foot-mats to protect the bottom from eddy scour. Method of construction and plant used stated in detail in Annual Report, 1891, pp. 3606-3610. Shown by photographs and model.

In the concentration of channel divided by islands, where a considerable arm of the river is to be closed, brush and stone dams are projected.

*Bank protection.*—(1) Continuous revetment of bank (first graded by water jet to slope of 1 on 4) by a mattress of brush, wire-fastened, moored and anchored, and loaded with stone, from two-thirds stage to bed of river, with foot-mat 240 feet wide on bed to protect from undermining. Method of construction and plant used stated in detail in Annual Report, 1891, pp. 3601-3606. Shown by photographs and model.

(2) Interrupted revetment of like construction, lengths of 1,100 feet with intervals of 300, 400, and 500 feet, has been tried as an experiment in economy; it is not yet regarded as fully tested.

(3) Spur dikes or brush mats, with brush cribs loaded with stone have been used where the direction of current promised economy by this method, and in places where depth was excessive. Shown by model.

*Dredging.*—As a measure of temporary relief to navigation during low water, it is proposed to build a hydraulic dredge for maintenance and guidance of channels across bars.



Contraction works have been mainly used at Plum Point and Lake Providence.

In Plum Point Reach, 20 miles of channel formerly shifting and shallow have been fixed in location and deepened. The dikes have built up 8 miles of solid bank, of which  $1\frac{1}{2}$  miles have been reveted. Maintenance of depth attained depends upon control of caving above.

In Lake Providence Reach, a series of dikes nearly continuous for 12 miles has improved the stability and depth of the channel, though in less degree than at Plum Point. The success of this work was dependent upon revetment undertaken in connection with it, where progress was interrupted by action of Congress. Works incomplete, and in present stage affording little permanent result.

Revetments, continuous for the reach, covered, have been used at many points on the river. Results generally successful. They aggregate  $23\frac{35}{100}$  miles.

Discontinuous revetments have been used at Fletchers Bend, covering a reach of 4,400 feet. Results of experiment still in question.

Spur dikes have been used in selected localities, covering an aggregate of 5 miles. Results generally successful.

These works, now disconnected, are designed as parts of a continuous system; permanence of results is dependent on completion of the system in order that the forces acting against the works may be those which they were designed to meet.

#### LEVEES.

From the beginning of its work, the Commission has aided the local authorities in the construction and building of levees where such work could be held to aid the channel works and bank protection; in late years this has been extended to levee work for land protection. The result of the combined effort has been a marked improvement of the levee system, and a marked diminution of the overflowed area, and of the crevasses, during recent floods.

Views of the Missouri River Improvement. Contributed by Lieut. Col. C. R. Suter, Corps of Engineers, president of Missouri River Commission.

Appropriations by the General Government for the improvement of the Missouri River were first made in 1876. The improvements were localized by the terms of the appropriation act, certain sums of money being allotted for work at specified localities. These appropriations were continued from one year to another, and new localities were added to the list from time to time.

This system of making appropriations prevented anything in the nature of a systematic improvement of the river as a whole, or even of continuous stretches of useful extent.

Following a report and project made in February, 1881, by Maj. C. R. Suter, Corps of Engineers, based upon the results of a general survey of the river, for which an appropriation had been made in 1878, there was made a general appropriation of \$850,000 in August 1882, making possible the beginning of a systematic improvement. In 1884, the Missouri River Commission was created by act of Congress, and its duties prescribed to be, "to superintend and direct such improvement of said river, and to carry into execution such plans for the improvement of the navigation of said river from its mouth to its head waters as may now be devised and in progress, and to continue and complete such surveys as may now be in progress, and to make such additional surveys, examinations, and investigations, topographical, hydrographical, and hydrometrical, and to consider, devise, and mature such additional plan or plans, and all such estimates as may be deemed necessary and best, to obtain and maintain a channel and depth of water in said river sufficient for the purposes of commerce and navigation, and under the direction and with the approval of the Secre-



tary of War, superintend, control, and expend for the purposes of this act all appropriations or unexpended balances heretofore made for the improvement of said river and which may hereafter be made for said river, or so much thereof as may be necessary."

Upon assuming their duties, the Commission approved the general project proposed by Maj. Suter in his report, referred to above, which contemplated the contraction of the width of the river "to such limits as will insure stability of regimen and approximate uniformity of slope, width, and depth."

The appropriation act divided the river into two sections, from the mouth to Sioux City, and from Sioux City to Fort Benton, Mont., the head of navigation; and the policy adopted in expending the appropriations was to apply them to the improvement of continuous stretches of the river, to be located where substantial benefits could soonest accrue.

The Commission have adopted the methods proposed by Maj. Suter for attaining the ends contemplated by the improvement, to be modified from time to time in the manner indicated by experience with the work. These methods embraced the grading of the banks by hydraulic graders, shore protection of continuous brush mattresses weighted with stone, and dikes with silt-catching devices for contracting the stream at places of excessive widths. Moreover caving banks and landslides, bringing into the stream numbers of large trees, necessitated extensive snagging operations.

The results attained by the application of these methods are shown by photographic views in this exhibit. These views are selected, as far as practicable, to show the successive steps of the improvement. Thus there are illustrated the weaving, lowering, and sinking of the mattresses; the grading of the banks; the building of the silt-catching dikes, and the effect of these dikes in the formation of banks by sedimentary deposit.

These works of improvement are still in progress under appropriations by Congress and under the direction of the Commission.

157. Single dikes under construction.
158. View showing incipient fill caused by dikes.
159. Showing completed fill.
160. Construction of dike and partly sunk mattress.
161. Dike and foot mattress ready for sinking.
162. Effect of dike in accumulating drift.
163. Grading party at work with hydraulic grader.
164. Mattress party at work.
165. Mattress sunk and stone bank revetment laid.
166. Snag boat *C. R. Suter*.
167. Grading bank with hydraulic jet.
168. Mattress party lowering mattress.
169. Side view of snag boat *C. R. Suter*.
170. Pulling snags.
171. Pile sinker for three-row pile dike.
172. Constructing foot mattress for dike.
173. System of pile dikes at Atchison.
174. System of pile dikes at Sioux City.
175. Resulting fill at Sioux City.

Muscle Shoals Canal. Contributed by Capt. George W. Goethals.



176. Shoal Creek Aqueduct, empty. Looking down.
177. Shoal Creek Aqueduct, empty. Looking up.
178. Lock No. 6, gate closed. Looking up.
179. Quarry at Lock No. 4. Looking up.
180. Locomotive towing.
181. Lock No. 9.
182. Lock No. 6.
183. Dam at channel above Lock A.
184. Shoal Creek Aqueduct, filled.
185. Lock A.
186. Lock A.
187. Lock B.
188. Lock No. 1.
189. Bluffs above Lock No. 3.
190. Dredge and Bluewater Waste Weir.
191. Bluewater Bridge and Dam.

The Muscle Shoals are the principal obstructions to navigation on the Tennessee River, and extend a distance of 38 miles, between the towns of Decatur and Florence, Ala., embracing Elk River Shoals, Big Muscle and Little Muscle Shoals. They divide 660 miles of navigable water of the Tennessee River into two sections, and before the construction of the canal prevented navigation from Knoxville and Chattanooga to the Ohio River.

A survey of the shoals with a view to constructing a canal was made in 1828, and under an appropriation of 400,000 acres of public land operations were begun by the State of Alabama in 1831.

This canal was opened for navigation in 1836, but about a year later, owing to a lack of funds for its maintenance, it was closed and entirely abandoned until 1872. During that year projects for the improvement and renovation of the canal were made by Maj. McFarland, Corps of Engineers. Work on the improvement was begun in 1875, and continued under the supervision of Lieut. Col. (then Captain) W. R. King, Corps of Engineers, until 1886, and afterwards under Lieut. Col J. W. Barlow, Corps of Engineers, until the canal was again opened to navigation, November 16, 1890.

The new canal includes the following improvements:

*Big Muscle Shoals Division.*—A canal 14.5 miles long, having nine locks, with a total lift of 85 feet and an aqueduct 900 feet long and 60 feet wide over Shoal Creek, with the necessary permanent dams and bridges over the several creeks and ravines; the canal trunk being from 70 to 120 feet wide at the water surface and 6 feet deep, and the locks 300 feet long, 60 feet wide, and having a depth of 5 feet of water on the miter sills.

*Elk River Shoals Division.*—A canal 1.5 miles long, with two locks, having lifts of 12 feet and from 5 to 9 feet respectively, and of same dimensions as the locks at Big Muscle Shoals.

*Little Muscle Shoals Division.*—A channel has been blasted through the bed rock of the river, and stone wing dams and retaining walls have been constructed to contract the waterway and to check the velocity of the current at certain points. In 1890 a project was approved for the construction of a lateral canal on the north bank 15,000 feet long, with a guard lock at the head and a lock at the foot, having a lift of 12 feet, and of same dimensions as the locks at Big Muscle Shoals.



192. East Breakwater at New Haven, Conn. Looking east and showing light-house on Southwest Ledge at southwest end of breakwater. Contributed by Col. D. C. Houston.

Breakwater is completed; is 3,450 feet long, extending from Southwest Ledge to Quixes Ledge.

*Construction.*—Heavy riprap, 12 feet top width at 12 feet above mean low water; outer slope of 1 on 2, inner of 1 on 1. This, with the middle and west breakwaters, is designed to form a harbor of refuge at the entrance to New Haven Harbor.

193. New York Harbor Improvement, hydraulic dredge *Reliance*. Contributed by Lieut. Col. G. L. Gillespie.

For description of this dredge and its method of operation see A, Models, 35a.

Ohio River Improvement. Contributed by Maj. A. Stickney.

194. Davis Island Lock and Dam, 5 miles below Pittsburg, Pa.  
 195. Davis Island Lock and Dam; lowering the dam.  
 196. Davis Island Lock and Dam; towboat with tow passing through lock.  
 197. Davis Island Lock and Dam; towboat with tow passing through navigable pass.  
 198. Davis Island Lock and Dam; view from north pier.  
 199. Davis Island Lock and Dam; lowering the dam.

See A, Models, No. 36.

Philadelphia Harbor Improvement. Contributed by Maj. Charles W. Raymond.

200. Steam pulsometer depositing on League Island material dredged from Windmill Island.

View from south embankment looking west.

201. Steam pulsometer depositing on League Island material dredged from Windmill Island.

View from top of pulsometer "Big Jim," looking west.

202. Discharge pipe of steam pulsometer "Big Jim."

View from south embankment looking northwest.

See A, Models, 37 and 38.

## MILITARY ENGINEERING.

### FORTIFICATIONS, AND COAST DEFENSE.

203. Fort Sumter, South Carolina, view of, just before the civil war. Contributed by Capt. F. V. Abbot.  
 204. Fort Sumter, South Carolina, interior just before final bombardment. Contributed by Capt. F. V. Abbot.  
 205. Forts Wadsworth, Staten Island, New York Harbor (in charge of Col. D. C. Houston, Corps of Engineers, U. S. Army). Contributed by Lieut. Col. G. L. Gillespie.

This fort, commenced in 1847, is situated on the west side of the Narrows, New York Harbor, and constitutes a part of the second line of defense of the southern water approach to New York City.



It is an inclosed work, built of granite, containing three tiers of guns in casemates and one in barbette, the lower tier being only a few feet above the water level.

206. Fort Lafayette, Long Island, New York Harbor. Contributed by Lieut. Col. G. L. Gillespie.

This circular casemated tower, situated on the east side of the Narrows, New York Harbor, was built in 1813, on plans prepared by Col. Joseph G. Swift, Chief of Engineers, U. S. Army.

Its armament was seventy-eight 32-pounder guns, arranged in two tiers of casemates surmounted by a third tier in barbette. It is founded upon riprap laid upon Hendricks Reef, 500 feet west of Long Island shore at the Narrows, which was originally covered by water 3 feet deep at mean low stage.

Under State act of March 20, 1807, the State commissioner of fortification ceded Hendricks Reef, measuring 30 acres, to the United States, November 16, 1812, "to be used and applied to the defense and safety of the city and port of New York and no longer," and in default thereof to revert to the State of New York.

During the civil war this place was used as a place of confinement for political prisoners.

It was destroyed by fire in 1868.

207. Fort Warren, Boston Harbor, east front. Contributed by Lieut. Col. S. M. Mansfield.

208. Fort Monroe, Va., view of. Contributed by Maj. C. E. L. B. Davis.

209. Fort Monroe, Va., view of. Contributed by Maj. C. E. L. B. Davis.

210. Old Forts, New York Harbor, Castle Garden, New York City. Contributed by Lieut. Col. G. L. Gillespie.

This circular casemated tower, with an armament of twenty-eight 32-pounder guns arranged in a single tier, was built in 1811, on plans prepared by Lieut. Joseph G. Totten, Corps of Engineers, U. S. Army (later brigadier-general and Chief of Engineers, U. S. Army).

It was first officially known as the Southwest Battery. After the war of 1812-'15 the name was changed to Castle Clinton, and the fort was occupied as the headquarters of the military commander of the district. In 1822 Castle Clinton was ceded by the United States to the city of New York, and the military headquarters were transferred to Governors Island.

In the year following (1823) the fort was altered for use as a place of public amusement, and the name again changed to Castle Garden. Since 1860 it has been used as the landing place for immigrants. The immigrant station was transferred in 1891 to Ellis Island, New York Harbor, and the city now proposes to convert Castle Garden building into a public aquarium.

211. Old Forts, New York Harbor; Castle Williams, Governors Island, New York. (In charge of Col. D. C. Houston, Corps of Engineers, U. S. Army). Contributed by Lieut. Col. G. L. Gillespie.

This circular casemated fort, 200 feet in diameter, and built of Newark red sandstone, was completed in 1811 on plans prepared by Col. Jonathan Williams, Corps of Engineers, U. S. Army, after whom it was named.

Its armament consisted of seventy-eight 32-pounder guns, arranged in three tiers of casemates surmounted by a fourth tier in barbette.

It constitutes a fort on the inner line of defense, and has always been used for military purposes.



211a. View of Fort Pickens, Fla., taken from the beach. Contributed by Capt. P. M. Price.

211b. View of Fort Barrancas, Fla., looking north ; old Spanish Fort in foreground, butts for rifle practice of garrison on right. Contributed by Capt. P. M. Price.

The enlarged photographs of some of our old forts are exhibited in connection with the models of typical batteries now in course of erection to show the progressive development of our seacoast fortifications during the present century to meet the progress in naval ordnance.

Castle Garden (Old Castle Clinton), Castle Williams, and Fort Lafayette are examples of forts built from 1807 to 1821. They are circular casemated towers, with several tiers of guns in casemates with wooden floors, surmounted by a tier of guns en barbette, supported upon arches of masonry. These forts are so weak, of such perishable material, as to have little permanent value. They were armed with 32-pounder cast-iron guns.

From 1819 to 1864 the system of fortifications known as the Totten system of seacoast forts, which was our first permanent system, represented in this exhibition by Forts Warren, Wadsworth, Adams, and Monroe, was constructed.

Gen. Abbot writes with reference to the successive improvements introduced by Gen. Totten during the construction of these works:

"They were radical, especially as to the details of the embrasure; he reduced the dangerous opening from 28 square feet to about 10 square feet, and this with an increased traverse and elevation for the gun. He was the first to introduce iron for defensive purposes into seacoast forts. This innovation resulted from a series of experiments carried out at West Point between the years 1852 and 1855. The throats of all embrasures constructed after 1858 were reënforced by 8-inch wrought-iron plates set into the masonry, and during the loading of the gun, the embrasure openings were closed by iron shutters 2 inches thick and proof against the largest grape.

\* \* \* \* \*

"The actual construction of works upon Gen. Totten's system covered a period of forty-five years, terminating about a year before the close of the civil war. They are masonry structures, usually placed but little above the water level, rising into one, two, or three tiers of casemates and surmounted by a tier in barbette. The scarps are built without any bonding of the masonry into the supporting piers (which would cause unequal settling on such sites as most of these works occupy). In all the latter works the scarps of the water fronts are 8 feet thick ; where they are backed by the piers of the casemates the reënforcement amounts to  $2\frac{1}{2}$  feet ; the masonry of the casemate arch, above the level of the communication arch, extends a solid support to the whole structure over 30 feet thick ; immediately in front of the guns, at the "recess," there is a small space where the thickness is reduced to 5 feet. In some of the earlier works the casemate arches were sprung at the level of the barbette tier and covered four guns each, the two of the second tier resting on a wooden floor ; but all the later scarps are solidly backed against single arches. In plan these works are usually hexagonal, often truncated on the land side. The superiority of the hexagon arises from its permitting the casemate guns on adjacent fronts to be fired in parallel planes at their extreme traverse (30 degrees). This covers and prevents a dead angle at the salient between them. Where there is a barbette tier, the guns, admitting of a traverse of 60 degrees from the front in each direction, strongly reënforce the fire of the casement guns over this naturally weak angle.



"So soon as the work of fortifying the coast was resumed after the civil war a radical change of system occurred. Masonry was provisionally abandoned, and earth was substituted for every kind of cover. Under this system, which continued until appropriations ceased in 1875, many batteries were built (similar to battery shown here in transparency of Fort Wadsworth in rear of the casemated fort) at important positions; and they will serve a good purpose, notwithstanding the rapid progress in guns which has occurred since they were built. After 1870 these earthen batteries were constructed to receive, if desired, the pattern of the King disappearing carriage designed for the 15-inch (smooth bore) gun."

\* \* \* \* \*

Views of experiments at Willets Point, New York. Contributed by Lieut. Col. W. R. King.

212. Explosion of submarine mine. November 19, 1889.

Charge, 50 pounds of mortar powder; submergence, 5 feet; distance, 350 feet; height of jet, 134 feet.

213. Destruction of schooner by submarine mine explosion. August 7, 1878.

Two charges, each 50 pounds of mortar powder, were suspended amidships, 10 feet apart and 3 feet below hull, giving a submergence of 7 feet; depth of water, 15 feet; height of jet, 75 feet; distance, 533 feet.

Time after explosion, 0.1 second.

214. Explosion of submarine mine. October 6, 1887.

Charge, 50 pounds of explosive gelatine; submergence, 5 feet; distance, 820 feet; height of jet, 185 feet.

215. Explosion of submarine mine, under ice. February 13, 1885.

Charge, 7.5 pounds of Judson powder; submergence, 5 feet; depth, 13 feet; thickness of ice, 8 inches; distance, 260 feet; height of jet, 45 feet; diameter of crater, 21.25 feet.

216. Explosion of submarine mine. May 2, 1890.

Charge, 150 pounds of mortar powder; submergence, 4.5 feet; distance, 450 feet; height of jet, 106 feet.

217. Mule decapitated by nitroglycerine explosion. June 6, 1881.

By 6 ounces of dynamite contained in a flannel bag and tied to his forehead.

218. Explosion of submarine mine. May 2, 1890.

Charge, 50 pounds of dynamite; submergence, 5 feet; distance, 700 feet; height, 129 feet.

219. Sims-Edison Fish Torpedo in motion. July 15, 1890.

Speed about 18 miles per hour.

220. Explosion of submarine mine.

#### WILLETS POINT, NEW YORK HARBOR, 1893.

Willets Point is a military post situated on the north shore of Long Island, about 15 miles east of New York City; opposite it on the mainland is Fort Schuyler, at the extremity of Throggs Neck, and these are the two posts that guard the northern entrance to New York Harbor, their distance apart being about 1,300 yards.

Willets Point was used as a hospital during the war and not occupied as a permanent post until after the disbanding of the Army of the Potomac. The existing fortifications were commenced in 1861; at the present time emplacements are be-



ing constructed for powerful modern guns. When these are completed the fortification will rank as a very strong one.

Located at the post are three institutions separate in their functions but all under the control of the post commander; they are the headquarters of the Battalion of Engineers, the United States Engineer Depot, and the United States Engineer School [of application].

The garrison consists of three companies of the Engineer Battalion (the fourth being stationed at West Point), numbering about 120 men each; the companies are organized as infantry, and besides being taught the ordinary duties of soldiers of the line are instructed in the special duties of sapping, mining, military bridge building, construction of field works, and in loading and planting submarine mines.

The noncommissioned officers are given instruction in making reconnaissances and topographical surveys and in photographic map printing. A species of trade school has been recently commenced where enlisted men in their spare time can get instruction and practice in carpentry, blacksmithing, care of engines and boilers, and kindred trades.

The depot provides for the storage of the pontoon bridge equipage; engineer, field, and bridge material; the care and purchase of insulated cable, submarine mines, and other torpedo material; the care, repair, and purchase of various surveying, astronomical, and geodetic instruments. There is also a valuable collection of models and war relics which has been added to from time to time and now occupies a handsome building in connection with an extensive professional library.

The engineer school of application was established in 1868, and designed originally to furnish a post-graduate course two or three years in length for officers newly assigned to the Corps of Engineers. In the year above mentioned a field astronomical observatory was erected, a regular series of meteorological observations begun, and practice commenced in reconnaissances and surveys. Military photography and hydrographic surveys were added in a few years, and as soon as the system of submarine mines, devised by Gen. Abbot, had reached a sufficiently advanced stage, "laboratories were prepared and officers and men given thorough instruction in the various branches of science upon which success in this new mode of warfare will depend."

In 1885 the school was reorganized and its scope well stated in the report of 1886, viz:

"The object of the school is primarily to form a body of officers and enlisted men who shall be theoretically and practically familiar with the fixed electrical torpedo defense of our harbors, and who, at the outbreak of war, with numbers too small to do the work themselves, would yet have the knowledge needed to supervise others in promptly putting down torpedo defenses.

"Its secondary object is to give practical instruction in military engineering, electricity, astronomy, surveying, and photography, and theoretical instruction in civil engineering."

The usefulness of the school has been extended by detailing each year several officers from the line of the Army for a nine-months course in electricity and submarine mining. In this period an officer learns all the details of the torpedo system, enough about electricity to understand all parts of the electrical apparatus, and obtains abundant practice in planting the mines.

In connection with the school, experiments are carried on which bear on the subjects taught and which are often of value as original investigations. Thus, tests are made of submarine cable purchased and stored; of the power of various high explosives in water or on shore, the form of crater produced, etc.; of powerful electro-magnets and the strength of field-surrounding dynamos. Here also are made the official trials of the Sims-Edison fish torpedo.



## LIGHT-HOUSES.

The exhibit of light-houses in the Engineer section of the War Department is made by authority, not as an exhibit of works carried on under the Secretary of War, but as showing a class of the numerous duties of officers of the Corps of Engineers of the Army.

Many of the most noted light-houses, calling for engineering skill of a high order to design and construct, such as Minots Ledge Light-house, on North Atlantic coast; Tillamook and North Seal, on Pacific coast; Stannards Rock on Great Lakes, etc., are not shown, due to the difficulty in securing proper photographs in such exposed localities.

Under the statutes of the United States relating to the Light-House Establishment the Light-House Board, under whose authority and direction all light-houses, buoys, beacons, and other aids to navigation along the coasts and navigable waters of the United States are located, constructed, and maintained, consists of the Secretary of the Treasury, ex-officio president of the Board; two officers of the Navy of high rank; two officers of the Corps of Engineers of the Army, and two civilians of high scientific attainments whose services may be at the disposal of the President, together with an officer of the Navy, and an officer of the Engineer Corps of the Army as secretary.

All preliminary surveys for sites of such works along the seaboard are made under the direction of the Superintendent of the Coast Survey, and those on the north-western lakes under the direction of the Corps of Engineers of the Army.

Officers of the Corps of Engineers superintend the construction and renovation of light-houses, and all plans, drawings, specifications, and estimates of cost of all illuminating and other apparatus, and of construction of towers, buildings, etc., connected with the Light-House Establishment are prepared by the Engineer officer detailed as secretary of the Board, or by such officers of the Engineers of the Army as may be detailed for that service. Detailed descriptions of the light-houses shown may be found in the various reports of the Light-House Board.

221. Aransas Pass Lighthouse, on the low island inside Aransas Pass, Tex. Contributed by Maj. J. B. Quinn.

It is a fixed white light of the fourth order, and the height of the focal plane is 65 feet. It was built in 1855.

222. Biloxi Light, at Biloxi, Miss. Contributed by Maj. J. B. Quinn.

It is a fixed white light of the fifth order. Height of the focal plane above mean high water, 60 feet. Was built in 1848.

223. Bolivar Point Light. Entrance to Galveston Harbor, Texas. Contributed by Maj. J. B. Quinn.

It is a fixed white light of the second order. Height of focal plane above mean high water 117 feet. Built in 1852.

224. Chandeleur Light, Louisiana. Northern extremity of Chandeleur Island, Louisiana. Contributed by Maj. J. B. Quinn.

It is a fixed white light of the fourth order, and the height of the focal plane above mean high water is 50 feet. Built in 1848.

225. Pass à L'Outre Light. At north side of entrance to Pass à L'Outre, mouth of Mississippi River. Contributed by Maj. J. B. Quinn.

It is a fixed white light varied by a white flash every 45 seconds. Height of focal plane above mean high water is 63 feet. It was built in 1855, and has settled 8 feet since built.



226. Dry Tortugas Light, Florida Reef. On the Loggerhead Key of the westernmost key of the Florida Reefs. Contributed by Maj. J. B. Quinn.

It is a fixed white light of the first order. Height of the focal plane above mean high water 149 feet. Was built in 1858.

227. Fort Point Light, Galveston Harbor, Texas. Contributed by Maj. J. B. Quinn.

It is a fixed white light of the fourth order. Height of focal plane above mean high water 47 feet. Built in 1881.

228. Fowey Rocks Light, off the north extremity of Florida Reefs. Contributed by Maj. J. B. Quinn.

It is a fixed white light of the first order, and the focal plane is 110 feet above mean high water. The structure is of iron and was built in 1878.

229. Front Beacon, Craighill Channel, Baltimore Harbor. Contributed by Capt. Eric Bergland.

Built in 1873. Foundation tubular, of cast iron, filled with concrete, the tube between high and low water being 2 inches thick, the other portions  $1\frac{1}{4}$  inches thick. This tube is 37 feet high and consists of two parts, the lower for a height of 12 feet being in the form of frustum of a cone, 30 feet in diameter at the base, 24 at the top; the upper part a cylinder of the same diameter as the top of the frustum of the cone to which it is joined. The tubing was cast in sections, the lower section being bolted to a grillage or flooring, consisting of four layers of timber each 12 inches thick.

230. Gasparilla Light, Florida. Entrance to Charlotte Harbor, Gulf of Mexico. Contributed by Maj. J. B. Quinn.

231. Poverty Island Light. Entrance to Green Bay, Mich. Contributed by Maj. William Ludlow.

232. Rear Beacon, Craighill Channel, Baltimore Harbor. Contributed by Capt. Eric Bergland.

Built in 1873. An open framework in the form of a frustum of a four-sided pyramid, the corner columns being of cast-iron disks, which are anchored to the masonry of the foundation piers.

The keeper's dwelling is of wood and stands with the base of the pyramid, through which passes an inclosed stairway, also of wood, leading to the lantern. The focal plane is 105 feet above ordinary tide. This light forms, with that shown from the front beacon, the range to guide up and down Craighill Channel, a deep-water route to the harbor of Baltimore.

233. Sandy Point Light-house, Chesapeake Bay, Maryland. Contributed by Capt. Eric Bergland.

Built in 1883. A brick tower 50 feet in height, octagonal in plan, resting on a cast-iron cylindrical caisson 35 feet in diameter and 32 feet high, filled with concrete.

This caisson was lowered into place from a working platform by means of set screws. It is composed of plates  $\frac{1}{2}$  inch thick, bolted securely together.

It stands in 12 feet of water and the focal plane is 52 feet above ordinary tide.

234. Sanibel Island Light, Sanibel Island, Florida. Contributed by Maj. J. B. Quinn.

It is a fixed white light of the third order, varied by a white flash every two minutes. Height of focal plane is 98 feet. Was built in 1884.



235. Sharps Island Lighthouse, Choptank River entrance. Contributed by Capt. Eric Bergland.

Built in 1882. Tower constructed of cast-iron plates  $\frac{5}{8}$  inch thick, bolted together to form a frustum of a cone 32 feet in height, 18 feet in diameter at the base, and 14 at the top.

Caisson foundation of cast-iron plates  $1\frac{1}{2}$  inches thick, bolted together to form a cylinder 30 feet in diameter and 30 feet high. The caisson was floated to the site by means of a cedar tank sunk on its site, and then filled with concrete made of cement, sand, and broken stone.

It stands in 10 feet of water and the light is 55 feet above the surface.

236. Ship Island Light, on the west end of Ship Island, Mississippi. Contributed by Maj. J. B. Quinn.

It is a fixed red light of the fourth order. Height of focal plane above mean high water, 73 feet. Was built in 1866.

237. South Pass East Jetty Light, Mississippi River. Contributed by Maj. J. B. Quinn.

It is a fixed red light of the fifth order, and the height of the focal plane above mean high water is 50 feet. Built in 1841.

238. Sombrero Key Light, Florida Reefs. Contributed by Maj. J. B. Quinn.

It is a fixed white light of the first order, and the iron structure was built in 1857. Height of the focal plane above mean high water, 142 feet.

239. Spectacle Reef Light, Lake Huron, Michigan. Contributed by Maj. William Ludlow.

PUBLIC WORKS IN DISTRICT OF COLUMBIA.

240. Perspective of the Building for the Library of Congress. Contributed by Bernard R. Green, Superintendent and Engineer.

This building, now under construction, located 1,000 feet eastward of the Capitol in Washington, D. C., is in charge of Brig. Gen. Thomas Lincoln Casey, with Bernard R. Green, superintendent and engineer, assisted by Paul J. Pelz, designer of the architectural features.

The reading room, 100 feet in diameter, occupies the rotunda in the center of the building, from which radiate the book stacks, each nine tiers high, lighted from four court yards.

The exterior walls are of granite from Concord, N. H., and the court walls of a cream white enameled brick trimmed with Maryland granite.

The main stair hall is to be white marble and the rotunda of colored marble.

The length of building 470 feet, width 340 feet, height to finial or dome lantern 190 feet.

Construction begun in 1889, to be finished in 1896, at total cost within \$6,000,000.

241. State, War, and Navy Building, Washington, D. C. Contributed by Col. Oswald H. Ernst, Superintendent Public Buildings and Grounds.

Designed by Alfred B. Mullett, Supervising Architect of the Treasury, who superintended the construction of the south and part of the east wing, under the direction of the Secretary of State. Ground broken for the south wing in 1871, and for east wing in 1872.



Mr. Mullet was succeeded by Wm. A. Potter, December 31, 1874, when south wing was nearly completed. Mr. Potter completed this wing and continued east wing, which he had carried to about mid-height of first story, when the construction was transferred to the War Department by act of March 3, 1875, and placed in the hands of Col. O. E. Babcock, Corps of Engineers, U. S. Army.

He was succeeded by Brig. Gen. (then Lieut. Col.) Casey, who completed the east and built the north, west, and center wings, finally completing the building in January, 1888.

242. View of Building for the Library of Congress during construction.

Contributed by Bernard R. Green, Superintendent and Engineer.

For description see above, No. 240.

243. Washington Monument. Contributed by Col. Oswald H. Ernst, Superintendent of Public Buildings and Grounds.

Height, 555 feet 5 inches—the highest masonry construction in the world.

Corner stone laid July 4, 1848. Built by a private corporation, "The Washington National Monument Society," to a height of 156 feet, where, in 1856, the work was suspended for the want of funds.

Congress decided in 1876 to complete it with Government funds. The foundation was found to be insufficient for the contemplated height and weight of the structure, and was widened and strengthened, and the monument carried through to completion in 1885 by Gen. (then Lieut. Col.) Thos. Lincoln Casey, Corps of Engineers, U. S. Army.

In addition to the above outlined facts the following remarks of Col. (now Brig. Gen. and Chief of Engineers) Thos. L. Casey, Corps of Engineers, made at the dedication of this monument February 21, 1885, are quoted:

"The duty has been assigned me of presenting the part taken by the General Government in the construction of this monument, and of delivering it to the President of the United States.

"You have heard from the First Vice-President of the Washington National Monument Society of the part taken by that distinguished body in the inception and partial construction of the monument and of its appeals, both to the people of the country and to Congress, for assistance in the great work so bravely undertaken.

"Whatever may have been the results of these appeals, no really effective proceedings were had in Congress having in view the completion of the monument, until July 5, 1876. On that day, Mr. Chairman, you introduced in the Senate a concurrent resolution, referring in terms to the Centennial of our National Independence and to the influence of George Washington in securing that independence, and closing as follows:

" 'Therefore, as a mark of our sense of honor due his name and his compatriots and associates—our Revolutionary fathers—we, the Senate and House [of Representatives in Congress assembled, in the name of the people of the United States, at this, the beginning of the second century of national existence, do assume and direct the completion of the Washington Monument in the city of Washington, and instruct the committees on appropriations of the respective Houses to propose suitable provisions of law to carry this resolution into effect.'

"Within two days from its introduction this resolution was passed unanimously by both Houses, and, in obedience to its instructions, a bill for the completion of the Washington Monument was at once reported in the House of Representatives, and became a law August 2, 1876. That statute appropriated \$200,000 for the completion of the monument, to be expended in four equal annual installments; provided for a transfer to the United States of the ownership of the portion of the shaft then built, and created a Joint Commission to direct and supervise the construction of



the monument, which Commission was to make a report each year to Congress. The Commission was to consist of the President of the United States, the Supervising Architect of the Treasury Department, the Architect of the Capitol, the Chief of Engineers of the United States Army, and the first vice-president of the Washington National Monument Society.

"The act further required 'that prior to commencing any work on the monument an examination should be made of its foundation in order to thoroughly ascertain whether it was sufficient to sustain the weight of the completed structure, and if the same should be found insufficient, then the further continuance of the work was not to be authorized by anything contained in the act until the further action of Congress.'

"From the early days of the construction there had been apprehensions that the foundation was not of sufficient size to sustain the column if carried to the height originally designed. These apprehensions which, just after the laying of the corner-stone, were shared by but few persons, had, as far back as 1853, become widespread, and were entertained by many intelligent people. In 1873, after a lapse of twenty years, the question of the sufficiency of the foundation was again the subject of discussion at this time by a committee of the House of Representatives.

"This was the select committee of thirteen, created to consider the practicability of completing the Washington Monument by the time of the Centennial celebration of the Declaration of Independence, July 4, 1876. During their deliberations they caused special investigations to be made concerning the stability of the existing structure. These investigations and the reports were made by capable engineers, and the conclusions drawn by them were to the effect that the existing foundation should not be subjected to any additional load whatever; in other words that it would be unsafe to increase the height of the incomplete shaft.

"It was hardly to be expected that the further examinations required by the act of August, 1876, would disclose anything different as to the condition of the foundation, nevertheless the Joint Commission secured the services of another Board of experienced engineers, who, after careful borings, examinations, and tests of the earth of the site, and due deliberation, reported on the 10th of April and 15th of June, 1877, that the existing foundation was of insufficient spread and depth to sustain the weight of the completed structure, but that it was feasible to bring the foundation to the required stability by hooping in the earth upon which it stood. These opinions were concurred in by most of the engineers who considered the subject, while they were quite as unanimous in the belief that to excavate beneath and put a new foundation under the old one would be hazardous in the extreme.

"On the 8th of November, 1877, the Joint Commission made its first report to Congress, announcing the decision of the engineers, and this report led to the enactment of the joint resolution of June 14, 1878, authorizing the Joint Commission to expend the sum of \$36,000, if they deemed it advisable, in giving greater stability to the foundation.

"Two years had now elapsed since the creation of the Joint Commission. They at once secured the services of an engineer and his assistant, and directed the chief to prepare a project for strengthening the existing foundation so that the obelisk could be carried to the desired height. This project, which necessarily included the form and dimensions of the finished monument, was completed and approved October 1, 1878, and active operations were immediately commenced. The project contemplated, first, the digging away of the earth from around and beneath the outer portions of the old foundation and replacing it with Portland cement concrete masonry; then, in removing a portion of the old masonry foundation itself from beneath the walls of the shaft and substituting therefor a continuous Portland cement concrete enlargement extending out over the new subfoundation. The weakness of the old foundation lay in the fact that it was too shallow and covered



an area of ground insufficient to sustain the pressure of the completed work. The strengthening consisted in the enlargement of the foundation by spreading it over a greater area and sinking it a greater depth into the earth. The work of excavating beneath the monument was commenced January 28, 1879, and the new foundation was finished May 29, 1880. It was impossible to properly enlarge the foundation with the funds granted in the joint resolution of June 14, 1878. A careful estimate of the cost, which accompanied the original project, amounted to about \$100,000, and accordingly, by the joint resolution of June 27, 1879, a further sum of \$64,000 was granted to complete the foundation. This proved to be more than sufficient, as the foundation cost but \$94,474.

"As completed, the new foundation covers two and a half times as much area and extends  $13\frac{1}{2}$  feet deeper than the old one. Indeed, the bottom of the new work is only 2 feet above the level of high tides in the Potomac, while the water which permeates the earth of the Monument Lot stands six inches above this bottom. The foundation now rests upon a bed of fine sand some 2 feet in thickness, and this sand stratum rests upon a bed of bowlders and gravel. Borings have been made in this gravel deposit for a depth of over 18 feet without passing through it, and so uniform is the character of the material upon which the foundation rests that the settlements of the several corners of the shaft have differed from each other by only the smallest subdivisions of the inch. The pressures on the earth beneath the foundation are nowhere greater than the experiences of years have shown this earth to be able to sustain, while the strength of the masonry in the foundation itself is largely in excess of the strains brought upon it. The stability of this base is assured against all natural causes except earthquakes or the washing out of the sand bed beneath the foundation.

"Having enlarged the foundation, the work upon the shaft was speedily commenced. The summer of 1880 was mostly taken up in building an iron frame within the shaft, preparing the hoisting machinery, and collecting the granite and marble needed in the construction. The first marble block was set in the shaft on the 7th of August, 1880, and the last stone was placed at the level five hundred on the 9th of August, 1884, thus consuming four seasons in finishing the shaft. The topmost stone of the pyramidion was set on the 6th of December, 1884, thus essentially completing the obelisk. Minor additions and modifications in the details of the interior of the shaft are still to be made, and some filling, grading, and planting are required for the terrace, but no work is proposed that can change the existing appearance or proportions of the monument.

"The masonry constructed by the Government is the best known to the engineering art, and the weight is so distributed that, subjected to a wind pressure of 100 pounds per square foot on any face, corresponding to a wind velocity of 145 miles per hour, the monument would have a large factor of safety against overturning. The marble is of the same kind as that in the monolithic columns of the Capitol, has a fine grain, is close and compact in texture, free from disintegrating impurities, and in this climate will endure for ages.

"Although the dimensions of the foundation base were originally planned without due regard to the tremendous forces to be brought into play in building so large an obelisk, the resources of modern engineering science have supplied means for the completion of the grandest monumental column ever erected in any age of the world.

"In its proportions the ratios of the dimensions of the several parts of the ancient Egyptian obelisk have been carefully followed.

"The entire height has been made slightly greater than ten times the breadth of base, producing an obelisk that, for grace and delicacy of outline, is not excelled by any of the larger Egyptian monoliths, while in dignity and grandeur it surpasses any that can be mentioned."



244. Washington Aqueduct. Cabin John Bridge. Contributed by Lieut. Col. G. H. Elliot.

The arch supports the masonry conduit, 9 feet in diameter, and the highway. The span is 220 feet and the rise is  $57\frac{1}{4}$  feet—the longest masonry arch in the world. Constructed 1857–1863. Capt. Montgomery C. Meigs, Corps of Engineers, U. S. Army, chief engineer; A. L. Rives, C. E., assistant engineer.

245. Washington Aqueduct. Griffith Park Bridge. Contributed by Lieut. Col. G. H. Elliot.

The arch supports the masonry conduit 9 feet in diameter and the highway. The span is 75 feet and the rise is 15 feet. Constructed 1857–1859. Capt. Montgomery C. Meigs, Corps of Engineers, U. S. Army, chief engineer; Charles G. Talcott, C. E., assistant engineer.

246. Washington Aqueduct. Rock Creek Bridge. Contributed by Lieut. Col. G. H. Elliot.

The two arched 48-inch mains carry about one-half of the Washington water supply and also support the highway. The span is 200 feet and the rise is 20 feet. Constructed 1858–1860. Capt. Montgomery C. Meigs, Corps of Engineers, U. S. Army, chief engineer; E. T. D. Myers, C. E., assistant engineer.

---

### C.—Photograph Albums.

(In duplicate.)

247. Building for the Library of Congress. (16 views.)  
 248. Willets Point; Fort Monroe; Old Fortifications. (71 views.)  
 249. St. Marys Falls Canal and Locks. (67 views.)  
 250. Light-houses. (69 views.)  
 251. Cascades Locks, Columbia River. (41 views.)  
 252. Upper Columbia River Improvement; Yaquina Bay; Coos Bay; Coquille River entrance. (45 views.)  
 253. Improvements of certain Rivers in South Carolina; Coosa River Improvement, Alabama; Muscle Shoals Canal, Tennessee River, Alabama. (41 views.)  
 254. Improvement of certain Rivers and Harbors in Georgia. (54 views.)  
 255. Great Kanawha River Improvement, W. Va.; Falls of Ohio River; Louisville and Portland Canal; Wabash River Improvement; Cumberland and French Broad Rivers Improvement. (70 views.)  
 256. Ohio River Improvement.  
 257. Allegheny River Improvement.  
 258. Muskingum River Improvement.  
 259. Monongahela River Improvement.



- 260. Boston Harbor; New York Harbor; Harlem and Hudson River Improvements; East River Improvement; Harbors East Coast Lake Michigan; Harbors of Duluth, Agate Bay, and Marquette; Galveston Harbor. (78 views.)
- 261. Mississippi River Commission Works. (55 views.)
- 262. Missouri Commission Works; Fox River Improvement; Illinois and Mississippi River Canal; Illinois River Improvement; Calumet River and Chicago Harbor. (65 views.)
- 263. Upper Mississippi River Improvement.

---

### D.—Charts, Maps, and Drawings.

#### RIVER AND HARBOR IMPROVEMENTS.

- 264. United States Snag Boat *Suwanee*, St. Augustine, Fla. Contributed by Maj. Mallery.
- 265. Two sets, elevation, plan, section, and detail of iron lock gates at Bremerhaven, copied from German drawings under the direction of G. Weitzel, major of engineers, U. S. Army. (Sheets A to F.)
- 266. Lake Champlain, cross sections of breakwaters. Contributed by Maj. M. B. Adams.
- 267. Columbia River Improvement, mouth of; drawings and maps. Contributed by Maj. Handbury.
- 268. East River, Hell Gate; map Ways Reef. Contributed by Lieut. Col. Gillespie.
- 269. East River; drawing; drill scow *Gen. John Newton*. Contributed by Lieut. Col. Gillespie.
- 270. Fox River, lower dam at Appleton. Contributed by Maj. Gregory.
- 271. Hudson River, Waterford to Hudson; map. Contributed by Lieut. Col. Gillespie.
- 272. See E, Engineer Publications, etc.
- 273. See E, Engineer Publications, etc.
- 274. Great Kanawha River, Lock and Dam, No. 2; Atlas of Drawings. Contributed by Col. Craighill.
- 275. Great Kanawha River Improvement; Atlas of Maps. Contributed by Col. Craighill.
- 276. See E, Engineer Publications, etc.
- 277. See E, Engineer Publications, etc.
- 278. Two sets, Plan of Crib Work as adopted by Bvt. Col. J. B. Wheeler, Maj. U. S. Engineers, for Piers of Lake Michigan Harbor.
- 279. See E, Engineer Publications, etc.
- 280. Reservoirs at Headwaters of the Mississippi. Winnebigoishish Dam. Contributed by Maj. Jones.



281. New York Harbor, improvement of. Maps. Contributed by Lieut. Col. Gillepsie.
282. See E, Engineer Publications, etc.
283. Two sets, Davis Island Dam, Ohio River, by Lieut. Col. W. E. Merrill, Corps of Engineers (in 12 sheets).
284. Potomac River Improvement, plan of. Contributed by C. E. L. B. Davis.
285. Potomac River. Design of Suspension Bridge. Contributed by Maj. C. E. L. B. Davis.
286. Outline map of the United States and Territories, prepared in the Office of the Chief of Engineers, U. S. Army, under the direction of Maj. H. M. Adams, Corps of Engineers, U. S. Army, showing the tonnage of the navigable rivers of the United States. Compiled from Annual Reports, 1890.
287. Map—Showing the location of Works and Surveys for River and Harbor Improvement. Compiled for the Index to the Reports of the Chief of Engineers, under the direction of Henry M. Robert, Major of Engineers, U. S. Army, 1879.

---

E.—List of Publications of the Engineer Department,  
U. S. A., including Reports of Explorations,  
Etc., conducted under other branches  
of the Department of War.

---

PROFESSIONAL PAPERS OF THE CORPS OF ENGINEERS OF THE  
UNITED STATES ARMY.

- No. 1. Bitumen : its varieties, properties and uses. Compiled from various sources, by Lieut. H. Wager Halleck. 8°. Washington, 1841.
- No. 2. A special report on the sea wall built in the year 1843 for the preservation of Ram Head, at the northwest end of Lovell's Island, by Col. S. Thayer. 8°. Washington, 1844.
- No. 3. Sustaining Walls : geometrical constructions to determine their thickness under various circumstances, by Capt. D. P. Woodbury. 8°. Washington, 1854.
- No. 4. Description of a system of military bridges with India-rubber pontons. Prepared for the use of the United States Army, by Capt. George W. Cullum. 8°. New York and Philadelphia, 1849.
- No. 5. An analytical investigation of the resistance of piles to superincumbent pressure, by Bvt. Lieut. Col. James L. Mason. 8°. Washington, 1850.
- No. 6. Report on the effect of firing with heavy ordnance from casemate embrasures, and also the effects of firing against the same embrasures with various kinds of missiles, by Bvt. Brig. Gen. Joseph G. Totten. 8°. Washington, 1857.



- No. 7. Treatise on the various elements of stability in the well-proportioned arch, with numerous tables of the ultimate and actual thrust. By Capt. D. P. Woodbury. 8°. New York, 1858.
- No. 8. Official report to the United States Engineer Department of the siege and reduction of Fort Pulaski, Georgia, February, March, and April, 1862. By Brig. Gen. Q. A. Gillmore. 8°. New York, 1864.
- No. 9. Practical treatise on limes, hydraulic cements, and mortars. By Q. A. Gillmore, A. M., brigadier-general of U. S. Volunteers, and major U. S. Corps of Engineers. 8°. Fourth edition. New York, 1872.
- No. 10. Longitude by Lunar Culminations. By Prof. W. H. C. Bartlett. 4°. Washington, 1845.
- No. 11. On the use of the zenith and equal altitude telescope in the determination of the latitude. By Capt. T. J. Lee. 4°. Washington, 1848.
- No. 12. Tables and formula useful in surveying, geodesy, and practical astronomy, including elements for the projection of maps, and instructions for field magnetic observations. By Thos. J. Lee. 8°. Third edition revised and enlarged. Washington, 1873.
- No. 13. Report upon the physics and hydraulics of the Mississippi River; upon the protection of the alluvial region against overflow; and upon the deepening of the mouths. By Capt. A. A. Humphreys and Lieut. H. L. Abbot. 4°. Philadelphia, 1861.
- No. 14. Siege artillery in the campaigns against Richmond, with notes on the 15-inch gun. By Bvt. Brig. Gen. Henry L. Abbot. 8°. Washington, 1867.
- No. 15. On the use of the Barometer on Surveys and Reconnaissances, with an appendix. By R. S. Williamson, major Corps of Engineers, brevet lieutenant-colonel, U. S. Army. 4°. New York, 1868.
- No. 16. Engineer and Artillery Operations against the Defenses of Charleston Harbor in 1863, with a supplement. By Q. A. Gillmore, major of engineers, brevet major-general, U. S. Army. 8°. New York, 1868.
- No. 17. Report on certain experimental and theoretical investigations relative to the quality, form, and combination of materials for defensive armor. By Bvt. Maj. W. R. King. 4°. Washington, 1870.
- No. 18. Report of the Geological Exploration of the Fortieth Parallel. By Clarence King, U. S. Geologist:
- Volume I. Systematic Geology. By Clarence King, U. S. Geologist. 4°. Washington, 1878.
  - Volume II. Descriptive Geology. By Arnold Hague and S. F. Emmons. 4°. Washington, 1877.
  - Volume III. Mining Industry. By James D. Hague, with geological contributions by Clarence King. 4°. and atlas. Washington, 1870.
  - Volume IV. Paleontology. By F. B. Meek, James Hall, and R. P. Whitfield. Ornithology. By Robert Ridgway. 4°. Washington, 1877.
  - Volume V. Botany. By Sereno Watson, aided by Prof. Daniel C. Eaton, and others. 4°. Washington, 1871.
  - Volume VI. Microscopical Petrography. By Ferdinand Zirkel. 4°. Washington, 1876.
  - Volume VII. Odontornithes. A Monograph on the Extinct Toothed Birds of North America. By Othniel Charles Marsh. 4°. Washington, 1880.
- No. 19. Report on béton aggloméré or coignet-béton and the materials of which it is made. By Q. A. Gillmore, major Corps of Engineers, brevet major-general U. S. Army. 8°. Washington, 1871.
- No. 20. A report on the defenses of Washington to the Chief of Engineers, U. S. Army, by Bvt. Maj. Gen. J. G. Barnard. 4°. Washington, 1871.



- No. 21. Report on the fabrication of iron for defensive purposes and its uses in modern fortifications, especially in works of coast defense. By Bvt. Maj. Gen. J. G. Barnard, Bvt. Maj. Gen. H. G. Wright, and Bvt. Lieut. Col. Peter S. Michie. With a supplement. 4°. Washington, 1871.
- No. 22. Report on the North Sea Canal of Holland and on the improvement of navigation from Rotterdam to the sea. By Bvt. Maj. Gen. J. G. Barnard. 4°. Washington, 1872.
- No. 23. Report upon Experiments and Investigations to develop a system of Submarine Mines for defending the Harbors of the United States. By Lieut. Col. Henry L. Abbot, Corps of Engineers, Bvt. Brig. Gen. U. S. Army. 4°. Washington, 1881.
- No. 24. Report upon the Primary Triangulation of the United States Lake Survey. By Lieut. Col. C. B. Comstock, Corps of Engineers, brevet brigadier-general, U. S. Army, aided by the assistants on the survey. 4°. Washington, 1882.
- No. 25. Report upon the Practice in Europe with the heavy Armstrong, Woolwich, and Krupp Rifled Guns, submitted by the Board of Engineers for Fortifications. 4°. Washington, 1883.
- No. 26. Notes on Mitering Lock Gates. By First Lieut. Harry F. Hodges, Corps of Engineers, U. S. Army. 4°. Washington, 1892.

## EXPLORATIONS AND SURVEYS.

History of the expedition under the command of Captains Lewis and Clarke to the sources of the Missouri, thence across the Rocky Mountains and down the River Columbia to the Pacific Ocean. Performed during the years 1804, 1805, and 1806, by order of the Government of the United States. 8°. 2 volumes. Philadelphia, 1814.

Exploratory travels through the western Territories of North America : comprising a voyage from St. Louis, on the Mississippi, to the source of that river, and a journey through the interior of Louisiana and the northeastern provinces of New Spain. Performed in the years 1805, 1806, and 1807, by order of the Government of the United States. By Zebulon Montgomery Pike, major Sixth Regiment United States Infantry. 4°. London, 1811.

Account of an expedition from Pittsburg to the Rocky Mountains, performed in the years 1819-1820, by order of the Hon. J. C. Calhoun, Secretary of War, under the command of Maj. S. H. Long, of the U. S. Topographical Engineers. Compiled from the notes of Maj. Long, Mr. T. Say, and other gentlemen of the party, by Edwin James, botanist and geologist to the expedition. 8°.

Narrative of an expedition to the source of St. Peter's River Lake Winnepeek, Lake of the Woods, etc., performed in the year 1823, by order of the Hon. J. C. Calhoun, Secretary of War, under the command of Stephen H. Long, U. S. Topographical Engineers. Compiled from the notes of Maj. Long, Messrs. Say, Keating & Colhoun, by William H. Keating, A. M., etc. 8°.

Geological Report of an examination made in 1834 of the Elevated Country between the Missouri and Red rivers. By G. W. Featherstonhaugh, U. S. Geologist. 8°. Washington, 1835.

Report of the Geological Reconnaissance made in 1835, from the seat of Government, by the way of Green Bay and the Wisconsin Territory, to the Coteau de Prairie, an elevated ridge dividing the Missouri from the St. Peter's River. By G. W. Featherstonhaugh, U. S. Geologist. 8°. Washington, 1836.

Report intended to illustrate a map of the hydrographical basin of the Upper Mississippi River, made by J. N. Nicollet, while in employ under the Bureau of the Corps of Topographical Engineers, 1838-1843. 8°. Washington, 1845.



Report of the exploring expedition to the Rocky Mountains in the year 1842, and to Oregon and North California in the years 1843-1844. By Bvt. Capt. J. C. Frémont. 8°. Washington, 1845.

New Mexico and California, containing:

Notes of a military reconnaissance from Fort Leavenworth in Missouri to San Diego in California, including part of the Arkansas, Del Norte, and Gila Rivers. By Lieut. Col. W. H. Emory.

Report of Lieut. J. W. Abert of his examination of New Mexico in the years 1846-1847.

Report of Lieut. Col. P. St. George Cooke of his march from Santa Fe, New Mexico, to San Diego, Upper California.

Journal of Capt. A. R. Johnson, First Dragoons. 8°. Washington, 1848.

Report of the survey of the northern and western boundary line of the Creek country, 1849. By Bvt. Capt. L. Sitgreaves and Lieut. J. C. Woodruff, Topographical Engineers, U. S. Army. 8°. Washington, 1858.

Report on the route from Fort Smith, Ark., to Santa Fé, N. Mex., made in 1849. By J. H. Simpson, lieutenant Topographical Engineers, U. S. Army. 8°. Washington, 1850.

Report of Lieut. Col. J. D. Graham on the subject of the boundary line between the United States and Mexico, 1850-1852. 8°. Washington, 1852.

Reconnaissance of routes from San Antonio to El Paso. By Bvt. Lieut. Col. J. E. Johnston, Lieut. W. F. Smith, Lieut. F. T. Bryan, Lieut. N. H. Michler, and Capt. S. G. French, of Quartermaster's Department; also, report of Capt. R. B. Marcy's route from Fort Smith to Santa Fé, and the report of Lieut. J. H. Simpson of an expedition into the Navajo country; and the report of Lieut. W. H. C. Whiting's reconnaissance of the western frontier of Texas. 8°. Washington, 1850.

Exploration of the Red River of Louisiana in the year 1852. By Randolph B. Marcy, captain Fifth U. S. Infantry, assisted by George B. McClellan, brevet captain U. S. Engineers. 8°. Text and maps. Washington, 1854.

Exploration and survey of the valley of the Great Salt Lake of Utah, including a reconnaissance of a new route through the Rocky Mountains. By Howard Stansbury, captain Corps of Topographical Engineers, U. S. Army. 8°. Philadelphia, 1852.

Report of an expedition down the Zuñi and Colorado rivers. By Capt. L. Sitgreaves, Corps Topographical Engineers. 8°. Washington, 1853.

Reports of explorations and surveys to ascertain the most practicable and economical route for a railroad from the Mississippi River to the Pacific Ocean, made under the direction of the Secretary of War, in 1853, 1854, 1855. 13 volumes. 4°. Washington, 1855-1860.

Preliminary report of explorations in Nebraska and Dakota in the years 1855, 1856, 1857. By Lieut. G. K. Warren, Topographical Engineers, U. S. Army. Reprint. 8°. Washington, 1875.

Report of reconnaissance from Fort Riley to Bridger's Pass and return, made in 1856. By Francis T. Bryan, lieutenant Topographical Engineers, U. S. Army. 8°. Washington, 1857.

Report of a survey for an Interoceanic Ship Canal across the Isthmus of Darien, connecting the Atlantic and Pacific oceans, 1857-1859. By N. Michler, lieutenant Topographical Engineers, U. S. Army. 8°. Text and maps. Washington, 1861.

Annual report of Capt. A. A. Humphreys, Topographical Engineers, in charge of Office of Explorations and Surveys, War Department. December, 1858. 8°. Washington, 1859.



Report upon the Colorado River of the West, explored in 1857 and 1858 by Lieut. Joseph C. Ives. 4°. Washington, 1861.

Report of explorations across the Great Basin of the Territory of Utah, for a direct wagon route from Camp Floyd to Genoa in Carson Valley, in 1859, by Capt. J. H. Simpson, Corps of Topographical Engineers, brevet brigadier-general U. S. Army. 8°. Washington, 1876.

Report of the exploring expedition from Santa Fé, N. Mex., to the junction of the Grand and Green rivers of the Great Colorado of the West in 1859, under the command of J. N. Macomb, captain Topographical Engineers, with geological report by Prof. J. S. Newberry, geologist of the expedition. 4°. Washington, 1876.

Report on the exploration of the Yellowstone River, by Bvt. Brig. Gen. W. F. Reynolds, with geological report of the exploration of the Yellowstone and Missouri Rivers. By Dr. F. V. Hayden, assistant, 1859-1860. 8°. Washington, 1868-1869.

Report on the construction of a military road from Fort Walla-Walla to Fort Benton. By Capt. John Mullan, U. S. Army. 8°. Washington, 1863.

Report of a reconnaissance of the Yukon River, Alaska Territory, July to September, 1869. By Capt. Charles W. Raymond. 8°. Washington, 1871.

Report of Lieut. Gustavus C. Doane upon the so-called Yellowstone expedition of 1870. 8°. Washington, 1873.

Report of a reconnaissance of the basin of the Upper Yellowstone in 1871. By Capt. J. W. Barlow, assisted by Capt. D. P. Heap. 8°. Washington, 1872.

Report of a reconnaissance of the Missouri River in 1872. By Thomas P. Roberts, assistant engineer, Northern Pacific Railroad. 8°. Washington, 1875.

Report on the Yellowstone expedition of 1873. By D. S. Stanley, colonel Twenty-second Infantry, brevet major-general, U. S. Army. 8°. Washington, 1874.

Report of a reconnaissance in the Ute country, made in the year 1873. By Lieut. E. H. Ruffner. 8°. Washington, 1874.

Report upon the reconnaissance of northwestern Wyoming, including Yellowstone National Park, made in the summer of 1873. By William A. Jones, captain of Engineers, U. S. Army. 8°. Washington, 1875.

Report of a reconnaissance of the Black Hills of Dakota, made in the summer of 1874 by William Ludlow, captain of engineers, brevet lieutenant-colonel, U. S. Army. 4°. Washington, 1875.

Report of an expedition up the Yellowstone River, made in 1875 by James W. Forsyth, lieutenant-colonel and military secretary, and F. D. Grant, lieutenant-colonel and aide-de-camp, under the orders of Lieut. Gen. P. H. Sheridan. 8°. Washington, 1875.

Report of a reconnaissance from Carroll, Montana Territory, on the Upper Missouri to the Yellowstone National Park and return, made in the summer of 1875 by William Ludlow, captain of engineers, brevet lieutenant-colonel, U. S. Army. 4°. Washington, 1876.

Notes on European surveys, compiled under the direction of C. B. Comstock, major of engineers, brevet brigadier-general, U. S. Army. 4°. Washington 1876.

Report of an examination of the Upper Columbia River and the territory in its vicinity in September and October, 1881. By Lieut. Thomas W. Symons, Corps of Engineers, U. S. Army. Royal 8°. Washington, 1882.

Geographical explorations and surveys west of the one hundredth meridian, in charge of Lieut. George M. Wheeler, Corps of Engineers, viz:

Preliminary report upon a reconnaissance through southern and southeastern Nevada made in 1869, by First Lieut. Geo. M. Wheeler, Corps of Engineers, U. S. Army, assisted by First Lieut. D. W. Lockwood, Corps of Engineers, U. S. Army 4°. Washington, 1875.



- Preliminary report concerning explorations and surveys principally in Nevada and Arizona, conducted under the immediate direction of First Lieut. George M. Wheeler, Corps of Engineers, 1871. 4°. Washington, 1872.
- Progress report upon geographical and geological explorations and surveys west of the one hundredth meridian in 1872, by First Lieut. George M. Wheeler, Corps of Engineers, in charge. 4°. Washington, 1874.
- Report upon the determination of the astronomical coördinates of the primary stations at Cheyenne, Wyoming Territory, and Colorado Springs, Colorado Territory, made during the years 1872 and 1873. First Lieut. Geo. M. Wheeler, Corps of Engineers, in charge, Dr. F. Kampf and J. H. Clark, civilian astronomical assistant. 4°. Washington, 1874.
- Report upon ornithological specimens collected in the years 1871, 1872, and 1873. By Dr. H. C. Yarrow and Prof. H. W. Henshaw. 8°. Washington, 1874.
- Catalogue of plants collected in the years 1871, 1872, and 1873, with descriptions of new species. By Mr. Sereno Watson and Dr. J. T. Rothrock. 8°. Washington, 1874.
- Preliminary report upon invertebrate fossils collected by the expeditions of 1871, 1872, and 1873, with descriptions of new species. By C. A. White, M. D. 8°. Washington, 1874.
- Systematic catalogue of the vertebrata of the Eocene of New Mexico, collected in 1874. By E. D. Cope, A. M. 8°. Washington, 1875.
- Instructions for taking and recording meteorological observations, and for preserving and repairing the instruments prepared for the use of field and astronomical parties, etc. By First Lieuts. R. L. Hoxie and Wm. L. Marshall. 8°. Washington, 1875.
- Catalogue of the mean declination of 2,018 stars between 0<sup>h</sup> to 2<sup>h</sup> and 12<sup>h</sup> to 24<sup>h</sup>, right ascension, and 10° and 70° of north declination, for January 1, 1875. Prepared under the direction of First Lieut. George M. Wheeler, Corps of Engineers, U. S. Army, by Prof. T. H. Safford. 4°. Washington, 1879.
- List of reports and maps of the United States geographical surveys west of the one hundredth meridian, George M. Wheeler, captain, Corps of Engineers, U. S. Army, in charge (second edition). 8°. Washington, 1881.
- Tables of geographic positions, azimuths, and distances, together with lists of barometric altitudes, magnetic declinations, and itineraries of important routes, prepared principally by First Lieut. M. M. Macomb, Fourth United States Artillery, 1883. Capt. George M. Wheeler, Corps of Engineers, U. S. Army, in charge. Royal 8°. Washington, 1885.
- Annual reports for the years 1873, 1874, 1875, 1876, 1877, 1878, 1879, 1880, 1881, 1882, and 1883.
- Report upon geographical and geological explorations and surveys west of the one hundredth meridian:
- Volume I. Geographical Report. 4°. Washington, 1889.
  - Volume II. Astronomy and Barometric Hypsometry. 4°. Washington, 1877.
  - Volume III. Geology. 4°. Washington, 1875.
  - Volume III. Geology. Supplement. 4°. Washington, 1881.
  - Volume IV. Paleontology. 4°. Washington, 1876.
  - Volume V. Zoölogy. 4°. Washington, 1875.
  - Volume VI. Botany. 4°. Washington, 1878.
  - Volume VII. Archæology. 4°. Washington, 1879.

## MISCELLANEOUS.

- Report from the Secretary of War with that of the Board of Engineers for Internal Improvement concerning the proposed Chesapeake and Ohio Canal. 8°. Washington, 1826.



- Report of examination and surveys, with a view of improving the navigation of the Holston and Tennessee rivers, in 1830, by S. H. Long, brevet lieutenant-colonel Topographical Engineers. 8°. Washington, 1875.
- Report in reference to the canal to connect the Chesapeake and Ohio Canal with the city of Baltimore, by Col. J. J. Abert, 1838. Reprinted for the use of the Engineer Department, U. S. Army. 4°. Washington, 1874.
- Reports on the construction of the piers of the aqueduct of the Alexandria Canal across the Potomac River at Georgetown, D. C. By Maj. William Turnbull, 1835-1840. Reprint. 4°. Washington, 1873.
- Essay on Meteorological Observations, by J. N. Nicollet. 8°. Washington, 1839.
- Report on the art of war in Europe in 1854, 1855, and 1856, by Maj. Richard Delafield, from his notes and observations made as a member of a "military commission to the theater of war in Europe." 4°. Washington, 1860.
- Military Commission to Europe, in 1855 and 1856. Report of Maj. Alfred Mordecai, of the Ordnance Department. 4°. Washington, 1860.
- Systems of military bridges in use by the United States Army, those adopted by the great European powers, and such as are employed in British India, with directions for the preservation, destruction, and reestablishment of bridges. By Brig. Gen. George W. Cullum. 8°. New York, 1863.
- Torpedoes: their invention and use, from the first application to the art of war to the present time. For the use of the officers of the Corps of Engineers. By W. R. King, captain of engineers and brevet major, U. S. Army. 8°. Washington, 1866.
- Reports on experimental firing with modern seacoast artillery to determine the elements of the trajectory in both direct and ricochet firing, etc. Compiled by Bvt. Maj. W. R. King. With a supplement by Maj. C. B. Reese. 8°. Washington, 1868.
- Counterpoise gun-carriages and platforms. By Capt. W. R. King. 4°. Washington, 1869.
- Organization of the bridge equipage of the U. S. Army, with directions for the construction of military bridges. Prepared by a Board of Engineer officers. 8°. With volume of plates. Washington, 1870.
- Report upon the removal of Blosson Rock in San Francisco Harbor, California, by R. S. Williamson, major Corps of Engineers, brevet lieutenant-colonel, U. S. Army, and W. H. Heuer, lieutenant Corps of Engineers. 4°. Washington, 1871.
- Design for an improved submarine tunnel comprising a brick arch within a cast or wrought iron skin, laid in a trench dredged for that purpose. By Lieut. Col. J. G. Foster, Corps of Engineers, brevet major-general, U. S. Army. 4°. Washington, 1872.
- Catalogue of the mean declinations of 981 stars between 12<sup>h</sup> and 26<sup>m</sup> of right ascension, and 30° and 60° of north declination, for January 1, 1875. Prepared under the direction of Bvt. Brig. Gen. C. B. Comstock, U. S. Army. By Prof. T. H. Safford. 4°. Washington, 1873.
- Translation of notes accompanying drawings concerning the construction of iron lock gates for the harbors of Weser River, Germany, by Bvt. Maj. Gen. G. Weitzel, U. S. Army. 4°. Washington, 1873.
- Report of a tour of inspection of European Light-House Establishments, made in 1873 by Maj. George H. Elliot, Corps of Engineers, U. S. Army, member and engineer secretary of the Light-House Board. 8°. Washington, 1874.
- Method of sinking cribs, devised by D. C. Houston, major of Engineers, brevet colonel U. S. Army. 4°. Washington, 1874.



- Report of the Board of Commissioners on the Irrigation of the San Joaquin, Tulare, and Sacramento valleys of the State of California. Lieut. Col. B. S. Alexander, Corps of Engineers, U. S. Army; Maj. George H. Mendell, Corps of Engineers, U. S. Army; Prof. George Davidson, U. S. Coast Survey, commissioners. 8°. Washington, 1874.
- Report on the effects of the sea water and exposure upon the iron-pile shafts of the Brandywine-shoal light-house. By John D. Kurtz, lieutenant-colonel of Engineers, brevet colonel U. S. Army, and Micah R. Brown, captain of engineers. 4°. Washington, 1874.
- Report upon the applicability of movable hydraulic gates and dams to the improvement of the Ohio River. By G. Weitzel, major of Engineers, brevet major-general U. S. Army, and W. E. Merrill, major of Engineers and brevet colonel U. S. Army. 8°. Washington, 1875.
- Memoranda relating to the improvement of the entrance to the Mississippi River by jetties. By A. A. Humphreys, brigadier-general and Chief of Engineers. 8°. Washington, 1875.
- Reclamation of the alluvial basin of the Mississippi River. Commission of Engineers. 8°. Washington, 1875.
- The Engineer Department, U. S. Army, at the International Exhibition, 1876. Capt. D. P. Heap, Corps of Engineers, in charge of the Engineer Section of the War Department participation of said Exhibition. 8°. Washington, 1884.
- Report on the Russian army and its campaigns in Turkey in 1877-1878. By F. V. Greene, first lieutenant in the Corps of Engineers, U. S. Army, and lately military attaché to the United States legation at St. Petersburg. 8°. Text and maps. New York, 1879.
- Report on bridging the Mississippi River between St. Paul, Minn., and St. Louis, Mo. By Bvt. Maj. Gen. G. K. Warren, major of Engineers. 8°. Washington, 1878.
- Report on current-meter observations in the Mississippi River, near Burlington, Iowa, during the month of October, 1879; illustrated by one sketch and forty-one plates. By Maj. Alexander Mackenzie, Corps of Engineers, U. S. Army. 8°. Washington, 1884.
- A lecture on the improvement of the Danube at Vienna, by Sir Gustav V. Wex (2 Papers); also, first and second treatises on the decrease of water in springs, creeks, and rivers. Translated by G. Weitzel, major of Engineers, brevet major-general, U. S. Army. 8°. Washington.
- Report on the International Exhibition of Electricity held at Paris, August to November, 1881. By David Porter Heap, major, Corps of Engineers, U. S. Army. 8°. Washington, 1884.
- Report upon the Third International Geographical Congress and Exhibition at Venice, Italy, 1881, accompanied by data concerning the principal Government Land and Marine Surveys of the World. By Capt. George M. Wheeler, Corps of Engineers, U. S. Army, commissioner and delegate. 4°. Washington, 1885.
- Analytical and topical index to the Reports of the Chief of Engineers and the officers of the Corps of Engineers, U. S. Army, upon works and surveys for river and harbor improvement, 1866-1879, Vol. I. By Lieut. Col. Henry M. Robert, Corps of Engineers. 8°. Washington, 1881.
- The same, 1880-1887, Vol. II. 8°. Washington, 1889.
- Course of lectures upon the defense of the seacoast of the United States, delivered before the United States Naval War College. By Bvt. Brig. Gen. Henry L. Abbot, U. S. Army, colonel, Corps of Engineers, November, 1887. 8°. New York, 1888.



- Irrigation in Egypt. By J. Barois, engineer-in-chief des Ponts et Chaussées, etc. Paris, 1887. Translated from the French by Maj. A. M. Miller, Corps of Engineers, U. S. Army, 1888. 4°. Washington, 1889.
- Notes on electricity in military and industrial engineering. By Col. Henry L. Abbot, Corps of Engineers, brevet brigadier-general, U. S. Army. Second edition, revised and enlarged, with a chapter on electric lighting by First. Lieut. John Millis, Corps of Engineers. 8°. Willets Point, 1888.
- Reports on construction of the State, War, and Navy Department Building, 1878-1888. By Col. T. L. Casey, lieutenant-colonel of Engineers. 8°. Washington.
- Reports on Washington National Monument. Completed by Col. T. L. Casey, lieutenant-colonel of Engineers, 1887. 8°. Washington.
- Regulations for the government of the Corps of Engineers, U. S. Army, 1889. 12°. Washington, 1889.
- Index of General Orders and Circulars, Headquarters Corps of Engineers and Office of the Chief of Engineers, in force May 9, 1892. Capt. John G. D. Knight, Corps of Engineers. 12°. Washington, 1892.
- Annual Reports of the Chief of Engineers to the Secretary of War for the years 1866, 1867, 1868, 1869, 1870, 1871, 1872, 1873, 1874, 1875, 1876, 1877, 1878, 1879, 1880, 1881, 1882, 1883, 1884, 1885, 1886, 1887, 1888, 1889, 1890, 1891, and 1892.
- Annual Reports of the Mississippi River Commission for the years 1880, 1881, 1882, 1883, 1884, 1885, 1886, 1887, 1888, 1889, 1890, 1891, and 1892.
- Annual Reports of the Missouri River Commission for the years 1884, 1885, 1886, 1887, 1888, 1889, 1890, 1891, and 1892.

## MISCELLANEOUS PAPERS.—I.

1. Report of Gen. J. G. Totten, Chief Engineer, on the subject of national defenses. 8°. Washington, 1851.
2. Extracts from "Constructions of iron applied to fortifications ; by O. Giese, captain of the royal Prussian engineers, and company commander." Translated by G. Weitzel, captain Corps of Engineers, brevet major-general, U. S. Army. 8°. Washington, 1867.
3. Memoir on foundations in compressible soils with experimental tests of pile-driving and formula for resistance deduced therefrom. Compiled by Bvt. Maj. Gen. Richard Delafield. 8°. Washington, 1868.
4. Report upon the decay and preservation of timber, by T. J. Cram, colonel U. S. Corps of Engineers, brevet major-general, U. S. Army. 8°. Washington, 1871.
5. Report upon experiments made by Assistant W. H. Hearding upon the compressive power of pine and hemlock timber, under the direction of Maj. D. C. Houston, Corps of Engineers. 8°. Washington, 1872.
6. Report on the compressive strength, specific gravity, and ratio of absorption of various kinds of building stone from different sections of the United States, tested at Fort Tompkins, Staten Island, New York, by Q. A. Gillmore, lieutenant-colonel Corps of Engineers, brevet major-general, U. S. Army. 8°. Washington, 1874.
7. Report upon the results of firings to determine the pressure of the blast from 15-inch smooth-bore guns, made at Staten Island, New York Harbor, in 1872 and 1873, by John Newton, lieutenant-colonel of Engineers, brevet major-general, U. S. Army, and Q. A. Gillmore, major of Engineers, brevet major-general, U. S. Army. 8°. Washington, 1874.
8. Report on blasting operations at Lime Point, Cal., on the 16th and 28th May, 1868, by G. H. Mendell, major of Engineers and brevet colonel, U. S. Army. 8°. Washington, 1868.



9. Statement with reference to the effect of the "Robbins process" for preserving piles from the attacks of the Teredo Navalis and Limnoria Terebrans, as ascertained by examination of piles in the wharf at or near Fort Point, San Francisco Harbor, California, by Lieut. Col. C. S. Stewart, Corps of Engineers. 8°. 10. An essay concerning important physical features exhibited in the valley of the Minnesota River and upon their signification, by G. K. Warren, major of Engineers and brevet major-general, U. S. Army. 8°. Washington, 1874.

## MISCELLANEOUS PAPERS.—II.

1. Contributions to the theory of blasting, or military mining, by H. Hofer, ordinary professor at the Royal Imperial School of Mines at Przibram. Translated by Capt. Charles W. Raymond, Corps of Engineers, U. S. Army. Parts I and II. 8°. Washington, 1881.
2. Hasty notes relating to military engineering in Europe, made in the autumn of 1883, by Bvt. Brig. Gen. Henry L. Abbot, lieutenant-colonel of Engineers. 8°. Washington, 1883.
3. Armored minimum embrasure gun-carriage, patented by Hermann Gruson, February 17, 1883. Translated from the German by Capt. Edward Maguire, Corps of Engineers, U. S. Army. 8°. Washington, 1884.
4. Studies on coast defense applied to the Gulf of Spezia, by Cæsar Guarasci, colonel of Engineers. Translated by First Lieut. G. McC. Derby, Corps of Engineers, U. S. Army. 8°. Washington, 1884.
5. Professional notes, by Capt. Edward Maguire, Corps of Engineers, U. S. Army. 8°. Washington, 1884.
6. Historical sketch of the fortification defenses of Narraganset Bay since the founding, in 1638, of the Colony of Rhode Island, by Bvt. Maj. Gen. George W. Cullum, colonel of Engineers (retired), U. S. Army. 8°. Washington, 1884.
7. Armor-plate trials at Magdeburg, 22d October, 1883. Twelve-inch guns against chilled cast-iron target. Translated from Mr. Gruson's official report, by Capt. Wm. H. Bixby, Corps of Engineers, U. S. Army. 8°. Washington, 1884.
8. Our seacoast defenses, by Eugene Griffin, first lieutenant Corps of Engineers, U. S. Army. 8°. New York and London, 1885.

## MISCELLANEOUS PAPERS.—III.

1. Report on transcontinental railways, 1883, by Col. O. M. Poe, lieutenant colonel of Engineers, colonel, aid-de-camp, and brevet brigadier-general, U. S. Army. 8°. Washington, 1883.
2. Memoir on a new kind of movable dam, by S. Janicki, engineer, director of the Moskva Navigation Company. Translated by Lieut. Col. William E. Merrill, Corps of Engineer, U. S. Army. 8°. Washington, 1883.
3. Report on the inland navigation and seaports of France, with list of canals and canalized rivers in the United States, by Lieut. Col. William E. Merrill, Corps of Engineers. 8°. Washington, 1890.
4. Report on the Fifth Congress of International Navigation, held at Paris, July 21 to July 31, 1892, by C. B. Comstock, colonel, Corps of Engineers, brevet brigadier-general, U. S. Army. 8°. Washington, 1892.
5. Report upon the routes for a ship canal between the Atlantic and Pacific oceans known as the Nicaragua route and the Darien or Atrato route, made in March and April, 1874, by Maj. Walter McFarland, United States Engineers, under the direction of the United States Interoceanic Canal Commission. 8°. Washington, 1893.
6. Reports upon building monument at Yorktown, Va., by Lieut. Col. William P. Craighill, Corps of Engineers, U. S. Army. 8°. Washington, 1882-'85.



## MISCELLANEOUS PAPERS.—IV.

1. The fortifications of to-day. Fire against models of coast batteries and paradoss. Horizontal and curved fire in defense of coasts. Translated under the direction of the Board of Engineers for Fortifications. Col. John Newton, Corps of Engineers, brevet major-general, U. S. Army, president of the Board. 4°. Washington, 1883.
2. Report in regard to the trial of Gruson's chilled cast-iron armor at Spezia, Italy, April, 1886, by Capt. H. M. Adams, Corps of Engineers, U. S. Army. 4°. Washington, 1886.
3. Thickness of cover for guns and magazines of fortifications. A study by John G. D. Knight, captain Corps of Engineers, U. S. Army, with a report thereon by the Board of Engineers and a criticism by Henry L. Abbot, colonel, Corps of Engineers, brevet brigadier-general, U. S. Army. 4°. Washington, 1893.

## PHOTOGRAPHIC VIEWS.

Photographs taken in connection with the geological exploration of the fortieth parallel. Clarence King, U. S. Geologist, in charge:

Volume I. Views in Wyoming and Northwestern Colorado.

Volume II. Views in Northern Utah and Idaho.

Volume III. Views in Nevada and Eastern California.

One set (216, two boxes) stereoscopic views.

Photographic views obtained in connection with geographical and geological explorations and surveys west of the one hundredth meridian, Lieut. Geo. M. Wheeler, Corps of Engineers, in charge:

One volume, 50 views, seasons of 1871, 1872, 1873.

One volume, 25 views, seasons of 1871, 1872, 1873, 1874.

One set (100) stereoscopic views, seasons of 1871, 1872, 1873.

One set (50) stereoscopic views, seasons of 1871, 1872, 1873, 1874.

## MILITARY MAPS.—ATLAS.

Armies of the Potomac and James; maps illustrating the operations of, from May 4, 1864, to April 9, 1865, including the battlefields of the Wilderness, Spottsylvania, North Anna, Totopotomoy, Cold Harbor, Bermuda Hundred, siege of Petersburg and Richmond, battlefields of Five Forks, Jetersville and Sailors Creek, High Bridge, Farmville, and Appomattox Court-House; also Harpers Ferry, Antietam, Chancellorsville, Fredericksburg, and South Mountain, with index sheet. From surveys made under direction of Bvt. Brig. Gen. N. Michler and Bvt. Lieut. Col. P. S. Michie, Corps of Engineers, U. S. Army.

## MILITARY MAPS.—PORTFOLIO.

Atlanta Campaign, Map I, embracing the region from the Tennessee River to the Oostanaula River, and exhibiting the works of the United States and Confederate forces, with the lines of march of the United States forces under command of Maj. Gen. W. T. Sherman in 1864. Compiled in the Engineer Bureau, War Department, 1875.

Atlanta Campaign, Map II, includes the region from Resaca on the north to Ackworth on the south, and exhibits the works of the United States and Confederate forces, with the lines of march of the United States forces under command of Maj. Gen. W. T. Sherman in 1864. Compiled in the Engineer Bureau, War Department, 1877.



Atlanta Campaign, Map III, includes the region extending from Rome, Kingston, and Cassville on the north, to include Dallas and Marietta on the south, and exhibits the works of the United States and Confederate forces, with the lines of march of the United States forces under command of Maj. Gen. W. T. Sherman in 1864. Compiled in the Engineer Bureau, War Department, 1876.

Atlanta Campaign, Map IV, illustrating the military operations of the; embracing the region from Pine, Lost, and Kennesaw mountains, south, to include Atlanta and its environs, exhibiting the lines of operations at Pine, Lost, and Kennesaw mountains, at Smyrna campground, along the Chattahoochie River, and the investment of Atlanta; Maj. Gen. W. T. Sherman, commanding, 1864. Compiled in the Engineer Bureau, War Department, 1874.

Atlanta Campaign, Map V, includes the region from the Chattahooche River, south, to Jonesboro and Lovejoys Station, and exhibits the works of the United States and Confederate forces, with the lines of march of the United States forces under command of Maj. Gen. W. T. Sherman in 1864. Compiled in the Engineer Bureau, War Department, 1877.

Atlanta, siege of, by the United States forces under command of Maj. Gen. W. T. Sherman, from the passage of Peach Tree Creek, July 19, 1864, to the commencement of the movement upon the enemy's lines of communication south of Atlanta, August 26, 1864, from a map prepared by Capt. O. M. Poe, Corps of Engineers, U. S. Army.

Blakely. Captured by the Army of West Mississippi, April 9, 1865. Showing the Confederate line of works and the position of and approaches by the United States forces.

Charleston City and Harbor, South Carolina. Showing the defenses of, also the works erected by the United States forces in 1863 and 1864, by Maj. Gen. Q. A. Gillmore, U. S. Volunteers.

Cumberland Gap, Tennessee: Operations of the Seventh Division under Brig. Gen. G. W. Morgan, during a portion of the year 1862. Compiled by Edward Ruger at Headquarters Department of the Cumberland.

Franklin, battlefield in front of: The United States forces under command of Maj. Gen. J. M. Schofield, November 30, 1864. Compiled under the direction of Col. W. E. Merrill, chief engineer, Department of the Cumberland.

Fort Fisher and vicinity: Surveyed under the direction of Bvt. Brig. Gen. C. B. Comstock, A. D. C. and chief engineer.

Fort Fisher, plans and sections of: Carried by assault by the United States forces Maj. Gen. A. H. Terry, commanding, January 15, 1865. Surveyed under the direction of Bvt. Brig. Gen. C. B. Comstock, A. D. C. and chief engineer.

Fort Henry and Fort Donelson, sketch showing the relative positions, also the roads connecting the two positions, drawn under the direction of Lieut. Col. J. B. McPherson, A. D. C. and captain of Engineers.

Fort Sumpter, S. C., at the time of its capture, February 18, 1865; showing the effect of the bombardment from Morris Island. By Maj. Gen. Q. A. Gillmore, commanding Department of the South.

Gettysburg, battlefield of, July 1, 2, and 3, 1863: Sheets 1, 2, and 3. Survey ordered by Bvt. Maj. Gen. A. A. Humphreys, and conducted under Bvt. Maj. Gen. G. K. Warren, major of Engineers.

Harper's Ferry, Va., including Maryland, Loudoun, and Bolivar Heights, and portions of South and Short mountains, with the positions of the defensive works; surveyed under the direction of Capt. N. Michler, Corps of Engineers, U. S. Army, August and September, 1863.



- Knoxville, Tenn. Approaches and defenses of; showing the positions occupied by the United States and Confederate forces during the siege. Surveyed under the direction of Capt. O. M. Poe, chief engineer, Department of the Ohio, during December, January, and February, 1863-1864.
- Marches of the United States forces under the command of Maj. Gen. W. T. Sherman, U. S. Army, during the years 1863, 1864, and 1865. Compiled by order of Gen. Sherman, under the direction of Bvt. Maj. W. L. B. Jenney, captain, A. D. C., U. S. Army, 1865.
- Nashville, battlefields in front of: United States forces, commanded by Maj. Gen. Geo. H. Thomas, December 15 and 16, 1864.
- Shiloh, battlefield of, near Pittsburg Landing, Tenn.; showing the positions of the United States forces under the command of Maj. Gen. U. S. Grant, U. S. Volunteers, and Maj. Gen. D. C. Buell, U. S. Volunteers, on the 6th and 7th of April, 1862; surveyed under the direction of Col. Geo. Thom, Chief of Topographical Engineers, Department of the Mississippi.
- Vicksburg, siege of, by the United States forces under the command of Maj. Gen. U. S. Grant, U. S. Volunteers, Maj. F. E. Prime, chief engineer; surveyed and constructed under the direction of Capt. C. B. Comstock, U. S. Engineers, and Lieut. Col. J. H. Wilson, A. I. G., first lieutenant Engineers.
- Virginia, central, 1862. Compiled in the Bureau of Topographical Engineers of the War Department.
- Virginia, northeastern, and vicinity of Washington. Compiled in Topographical Engineers office at division headquarters of Gen. Irvin McDowell, January 1, 1862, and corrected under direction of Topographical Engineers, August 1, 1862.
- Virginia, extract of military map of northeast, showing forts and roads about Washington, 1865.

## TOPOGRAPHICAL MAPS.—PORTFOLIO.

- Alluvial Valley of the Mississippi River from the head of St. Francis Basin to the Gulf of Mexico, showing lands subject to overflow, location of levees, and trans-alluvial profiles, by the Mississippi River Commission, 1887 (in 8 sheets).
- Arizona, Department of, sheets 1 and 3. Compiled by Lieut. J. C. Mallery, Corps of Engineers, and revised to 1875.
- Arizona, Territory and Department of; by First Lieut. T. A. Bingham, Corps of Engineers, U. S. Army, 1885.
- Black Hills, reconnaissance of, with troops under command of Lieut. Col. G. A. Custer, Seventh Cavalry; by Capt. William Ludlow, Corps of Engineers, July and August, 1874 (in 3 sheets).
- California and Nevada, with parts of Utah and Arizona; prepared in the office of the Chief of Engineers, U. S. Army, 1879.
- Carroll, Montana Territory, to the Yellowstone National Park and return; reconnaissance by Capt. William Ludlow, Corps of Engineers, chief engineer Department of Dakota, in July, August, and September, 1875.
- Colorado River of the West, Map No. 1; explored by First Lieut. Joseph C. Ives, Topographical Engineers, 1858.
- Columbia River, entrance to; by Maj. Thos. H. Handbury, Corps of Engineers, U. S. Army, 1889 (in 2 sheets).
- Columbia, map of the Department of the; by Lieut. Thos. W. Symons, Corps of Engineers, fourth edition, 1892.
- Crib work, plan of, as adopted by Bvt. Col. J. B. Wheeler, major of Engineers, for piers of Lake Michigan harbors.
- Dakota Territory, by Capt. D. P. Heap, Corps of Engineers, 1872. Revised and corrected by Capt. Edward Maguire, Corps of Engineers, 1881.



- Dakota, Department of, including Minnesota, Dakota, and Montana ; by Lieut. John Biddle, Corps of Engineers, 1886.
- Dodge, Fort, Kans. to Camp Supply, Indian Territory. Roads from ; by First Lieut. E. H. Ruffner, Corps of Engineers, U. S. Army, chief engineer, Department of the Missouri, 1872.
- Florida, map of the State of ; compiled in the Bureau of Topographical Engineers, 1856.
- Indian Territory, military map of the ; by First Lieut. E. H. Ruffner, Corps of Engineers, chief engineer, Department of the Missouri, 1875 (in 4 sheets).
- Kansas and Texas, States of, and Indian Territory, with parts of the Territories of Colorado and New Mexico ; prepared in the office of the Chief of Engineers, U. S. Army, 1867. Second edition, with corrections, issued in 1874 (in 2 sheets).
- Missouri, Department of the, outline map of a portion of ; by First Lieut. O. M. Carter, U. S. Engineers, chief engineer, Department of the Missouri, 1884 (in 4 sheets).
- Montana Territory, by Capt. D. P. Heap, Corps of Engineers, 1872.
- Nebraska and Dakota and portions of the States and Territories bordering thereon; by Bvt. Maj. Gen. G. K. Warren, major of Engineers, 1867.
- Nevada, south and southwestern, map showing detailed topography of the country traversed by the reconnaissance expedition through; in charge of Lieut. G. M. Wheeler, Corps of Engineers, 1869.
- New Mexico and Utah, explorations and surveys in; by Capt. J. N. Macomb, Topographical Engineers, 1860.
- New Mexico and Arizona, Territories of; prepared in the office of the Chief of Engineers, U. S. Army, 1879.
- New Mexico, northwestern; prepared in the office of the Chief Engineer, Department of the Missouri, 1883.
- New Mexico, southwestern ; prepared in the office of the Chief Engineer, Department of the Missouri, 1883.
- Niagara Ship Canal, sketch of parts of Niagara and Erie counties, New York, showing approximately the routes of various lines surveyed for the, 1867; by Bvt. Col. C. E. Blunt, lieutenant colonel of Engineers U. S. Army; also profiles (in 2 sheets).
- Platte; reconnaissance of routes in and leading from the Department of the; by Capt. W. S. Stanton, Corps of Engineers, 1875, 1876, and 1877.
- Platte, that portion of the Department of the, and adjacent territory west of the one hundred and third meridian ; by First Lieut. Hiram M. Chittenden, Corps of Engineers, U. S. Army, 1889 (in 2 sheets).
- Texas, southwestern, military map; 1881, by Capt. W. R. Livermore, Corps of Engineers, U. S. Army.
- Texas, western, military map of, 1884; by Capt. W. R. Livermore, Corps of Engineers, U. S. Army.
- Texas, western, survey of, 1883-1884, sheets 1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, and 15; by Capt. W. R. Livermore, Corps of Engineers, U. S. Army.
- Texas to Fort Yuma, California, outline map showing a new route from, for cattle, droves and trains en route to California; by Capt. L. C. Overman, Corps of Engineers, U. S. Army.
- United States, map of the; prepared in the office of the Chief of Engineers, U. S. Army, 1885. Corrected to December, 1889.
- United States, map of the territory of the, west of the Mississippi River; prepared in the office of the Chief of Engineers, U. S. Army, 1883.



- Upper Geyser Basin; drawn under the direction of Capt. Wm. Ludlow, Corps of Engineers.
- Washoe District, Nevada, outline map of, showing Comstock Lode, locations of mineral claims, shafts, mills, mining towns, etc., 1879; by First Lieut. Geo. M. Wheeler, Corps of Engineers, U. S. Army, 1876 and 1877.
- Washoe mining region, Nevada, topographical map of; by First Lieut. Geo. M. Wheeler, Corps of Engineers, U. S. Army, 1876 and 1877 (in 2 sheets).
- Western Territories, sheet No. 3; prepared by Maj. G. L. Gillespie, Corps of Engineers, U. S. Army, 1876.
- Yellowstone Lake and the valley of the Yellowstone River, sketch of the; route of Capt. J. W. Barlow and D. P. Heap, Corps of Engineers, in their reconnaissance of that region during the summer of 1871.
- Yellowstone National Park, Big Horn Mountains, and adjacent territory; prepared in the office of the chief engineer, Military Division of the Missouri, 1881.
- Yukon River, the, Alaska, from Fort Yukon to the sea; by Capt. Chas. W. Raymond, Corps of Engineers, U. S. Army, 1871.

## SURVEY OF NORTHERN AND NORTHWESTERN LAKES.—PORTFOLIO.

- Detroit River. 1 chart.
- Erie, Lake. 12 charts.
- Huron, Lake. 8 charts.
- Mackinac, Straits of. 1 chart.
- Michigan, Lake. 15 charts.
- Ontario, Lake. 6 charts.
- Saint Clair, Lake. 1 chart.
- Saint Clair River. 1 chart.
- Saint Lawrence River. 6 charts.
- Saint Marie, River. 3 charts.
- Superior, Lake. 14 charts.

## MISCELLANEOUS MAPS AND PLANS.

- Arkansas River, map of the, from Little Rock, Ark., to the mouth. By H. S. Taber, captain, U. S. Corps of Engineers (in 22 sheets). 1886.
- Arkansas River, map of the, from Wichita, Kans., to Fort Gibson, Ind. T. By Major M. B. Adams and Capt. H. S. Taber, U. S. Corps of Engineers (in 36 sheets). 1889.
- Davis Island Dam, Ohio River. By Lieut. Col. W. E. Merrill, Corps of Engineers (in 12 sheets). 1889.
279. Des Moines Rapids, Locks, and Canal of the Mississippi River, detailed drawings of. By Capt. A. H. Burnham, Corps of Engineers (in 39 sheets). 1872.
- Experimental firing at Fort Monroe, Va., and Fort Delaware, Del., November and December, 1868; record of.
- Geographical surveys west of the one hundredth meridian. By Capt. George M. Wheeler, Corps of Engineers. 1878.
273. Great Kanawha River, West Virginia, detailed drawings of Lock and Dam, No. 7. By Col. Wm. P. Craighill, Corps of Engineers, U. S. Army (in 16 sheets). 1892.
272. Kampsville Lock and Dam, Illinois River, Illinois; detailed drawings of. By Capt. W. L. Marshall, Corps of Engineers, U. S. Army (in 14 sheets). 1892.
277. Michigan, Lake: plans of different wooden structures used in improving harbors on (in 21 sheets). 1869.
- Mississippi River from Lake Itasca to the Falls of St. Anthony, map of. By Capt. Chas. J. Allen, Corps of Engineers, U. S. Army (in 17 sheets). 1881.



- Mississippi River from the Falls of St. Anthony to the junction of the Illinois River, map of. By Maj. A. Mackenzie, Corps of Engineers, U. S. Army (in 29 sheets). 1887-1888.
- Mississippi River between the mouth of the Illinois and the mouth of the Ohio River, map of. By Col. J. H. Simpson, Corps of Engineers, U. S. Army (in 11 sheets). 1878.
- Mississippi River, Lower, preliminary map of, from the mouth of the Ohio River to the Head of the Passes. Mississippi River Commission (in 37 sheets). 1881-1885.
- Mississippi River, survey of the, made under the direction of the Mississippi River Commission (sheets Nos. 3 to 69 and 101 to 114). 1885-1892.
- Missouri River, map of the. By Maj. Charles R. Suter, Corps of Engineers, U. S. Army (in 45 sheets). 1879-1882.
282. Ohio River, improvement of the Falls of the, Locks of the Louisville and Portland Canal. By G. Weitzel, Major of Engineers (in 8 sheets). 1870.
- Ohio River, map of the. By Maj. W. E. Merrill, Corps of Engineers (in 41 sheets). 1881.
- Rivers and Harbors, sketches illustrative of reports and projects for the improvement of certain.
276. St. Marys Falls Canal and Locks, Michigan; detailed drawings of, made under the direction of Lieut. Col. G. Weitzel, Maj. F. U. Farquhar, and Lieut. Col. O. M. Poe, Corps of Engineers, U. S. Army (in 17 sheets). 1882, 1883, 1884.
- Water communication between the Mississippi River and the Atlantic Ocean by way of the Tennessee and Coosa Rivers and the rivers of Georgia and connecting canals; sketch showing the proposed line of, under direction of Maj. Walter McFarland, Corps of Engineers, U. S. Army (in 8 sheets).
- White River, map of the, from its mouth to Bedford, Ind., on the East Fork, and to Gasport, Ind., on the West Fork. By Maj. Jared A. Smith, Corps of Engineers (in 17 sheets). 1878.
- White River, map of the, from Forsythe, Mo., to its mouth. By H. S. Taber, captain, U. S. Corps of Engineers (in 43 sheets). 1888.
- Yellowstone River, map of the, from Fort Keogh to Fort Buford. By Lieut. Edward Maguire, Corps of Engineers, U. S. Army (in 44 sheets). 1878.
- Yellowstone River, map of the, from Fort Keogh to Junction City. By Lieut. Edward Maguire, Corps of Engineers, U. S. Army (in 33 sheets). 1879.



























War department Exhibit World's Columbian exposition, Chicago, Illinois 1893  
. Corps of engineers, U. S. army. Catalogue

Washington 1893

Techn. 1440 f

urn:nbn:de:bvb:12-bsb11889676-5